Restoration of California grasslands and depressed basins: UCD's Putah Creek Riparian Reserve's Ecosystems Enclosure

Report by: Students of UC Davis' Restoration Ecology Class (ENH 160), Spring 2009, compiled by Valerie Eviner

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Notes:
This document is a product from UC Davis' Restoration Ecology class (ENH 160) in the spring of 2009, and is a result of the hard work of the students. Syntheses sections derive from class discussions, and 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, or entire documents), some figures, and some entire reports are missing.

Acknowledgements:

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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 UC Davis' Putah Creek Riparian Preserve, and the Restoration Ecology Class (ENH 160) at University of California, Davis. Putah Creek Riparian Reserve 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 access to lab students for monitoring and observational activities
- lecturing in class about the challenges of implementing restoration projects, and providing background information on Bobcat Ranch and its management goals.

The overall goal of class project was to develop a restoration handbook for the "basins" section of the Ecosystems Enclosure. 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. 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. 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. Results of these discussions can be found in the "project synthesis" section. In addition, the end of each student's individual report includes a revised management plan to encompass their goal, in addition to a broader suite of goals.

A full description of the students' assignment can be found in the Appendix.
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's upland and freshwater wetlands, and pointing to some key holes in our scientific understanding that will aid with the implementation of restoration and management programs. The management recommendations are very preliminary due to time limitations, but the literature reviews and lists of trade-offs should provide important information for those managing California grasslands and more mesic areas.

Overview of our project on the Putah Creek Riparian Reserve:

UC Davis' Putah Creek Riparian Reserve is an approximately 640 acre area, along 5.5 miles of Putah Creek, in and adjacent to the UC Davis campus. This reserve consists of a variety of habitats, including: streams, riparian zones, grassland ecosystems and wetlands, which are managed for mitigation and conservation of plant and wildlife species, as well as for teaching and research. There are a number of long-term restoration sites in this reserve that are exemplary in their success, particularly in native grass restoration.

Our class project focused on a small area of the reserve, the "ecosystem enclosure" area, which was formerly managed for experimental purposes by the wildlife department at UCD. This area consists of upland habitats, a constructed wetland, and some former fish ponds (now depressed basins that vary in conditions from ephermeral wetlands to more mesic-type uplands). Its general goals and requirements include:

- minimize fire risk (this is particularly important, since the UCD aquatic research facility is adjacent to the site)
- take advantage of the habitat diversity to enhance native diversity
- increase native forbs in restoration
- control exoticx with minimal time/mechanical input
- promote Swainson's hawks and burrowing owls (not a requirement at this particular site, but is part of the mission of other areas of the reserve, and this site could potentially contribute to that).

Aerial photo of the "ecosystem enclosure" area.

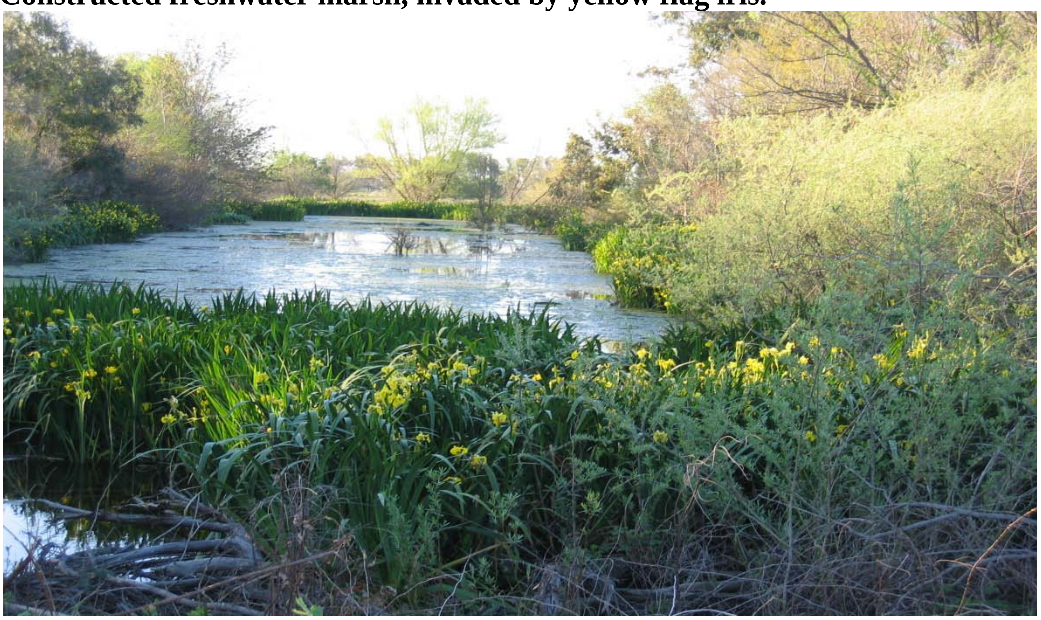
Our overall class goals included:

1. For upland areas:
    a. How can we maintain the native grass restoration projects and keep out exotics? (In particular, can this be done at low management intensity?)
    b. How can we promote native forb establishment?

Native grass plantings (small plants in rows) invaded by medusahead (brighter green, dense patches).

2. In the freshwater marsh:
    a. How do we promote native plants and wildlife, and inhibit exotic plants?
    b. Which natives are best to promote?

Constructed freshwater marsh, invaded by yellow flag iris.



3. In the basins (former experimental fish ponds, which are now depressed basins that range from ephermeral wetlands to more mesic upland conditions):

a. What are the site conditions of each of these basins?
b. What species are most suited to each basin?
c. Which weeds are most likely to be problematic in each basin?
d. How can these basins best contribute to the conservation and restoration of diverse habitat types and species, particularly in context of the surrounding area and overall reserve goals?

Foreground- upland invaded area, "gray" pool in background- one of the depressed basins.

<u>Lab characterization of basins:</u>

The lab section of the class surveyed the basins to determine the current condition of each, and the likely species/system each would support for restoration. A summary of characteristics is in the table below, with each basin being identified on the map below that.

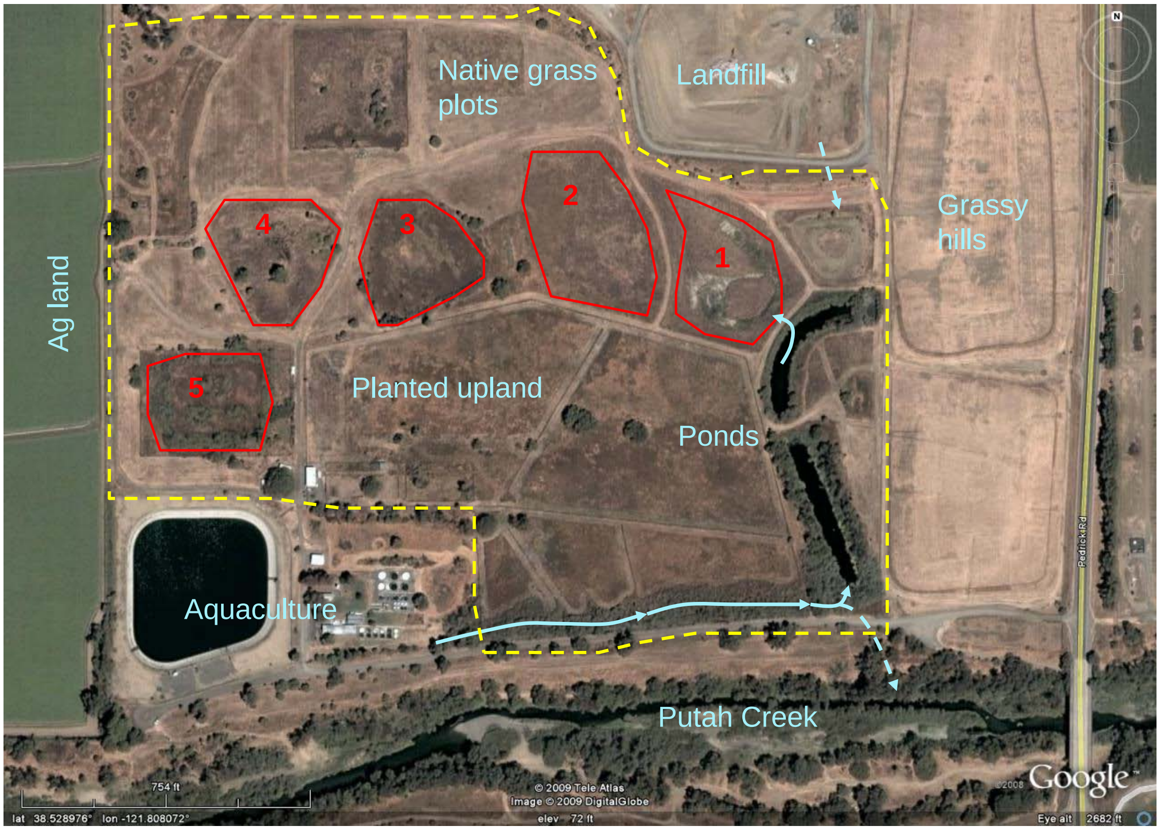
Vegetation was determined by the line-point intercept method in basin 3, and due to time constraints, in the other basins, dominants were noted after walking transects through the basins.

Soil water infiltration was determined using a disk infiltrometer at 2 locations per basin. Soil compaction was determined with an analog compaction tester. Four soil cores were collected per basin and bulked, and tested for soil moisture (gravimetric), soil organic matter (ash-free combustion loss), and soil nutrients were determined with an agricultural test kit, that colorimetrically determines whether soil N, P, and K are high, medium, or low (see below for details of levels).

Basin #	**Size (ha)**	**Vegetation dominants**	**Soil moisture-April**	**Water infiltration rate (mL/min)**	**Soil organic matter (%)**	**Soil compaction, depth**	**Soil N**	**Soil P**	**Soil K**
1	0.94	cattails, annual grass	11.8% (average, but had standing water in sections)	0.86	9.4%	variable- shallow to deep soil until compact layer	Low	Low	Low
2	10.82	annual grass, pasture grass (e.g. orchard grass)	13.9%	0.45	5.7%	Shallow	Low	Low	High
3	0.69	willow and other shrubs, annual grasses, musk thistle, high litter, valley oak, mustard, walnut	16.2	1.07	5.1%	Shallow	Low	Low	Low
4	0.75	annual grass, willow, blackberry, elderberry	10%	0.33	4.9%	Shallow	Low	Med.	Med
5	0.71	pepperweed, himalayan blackberry, milk thistle, elderberry, rumex sp. annual grass	15.6%	.36	5.3%	Shallow	Low	Low	Low
Uplands adjacent to basins		annual grass, milk thistle	12%	0.9	4.6%	Medium to deep	Low	Low	Low

N “low” for all- approximately 40 lbs/acre in top 6” soil
P- “low” approximately 6 lbs/acrew in top 6” soil, 20 for medium (med) (basin 4)
K- “low” 40 lbs/acre 6” soil, “medium” 80 lbs/acre 6” soil (basin 4), “high” 160 lbs/acre (in basin 2)

Basin map



Basin 1

Basin 2

Basin 3

Basin 4

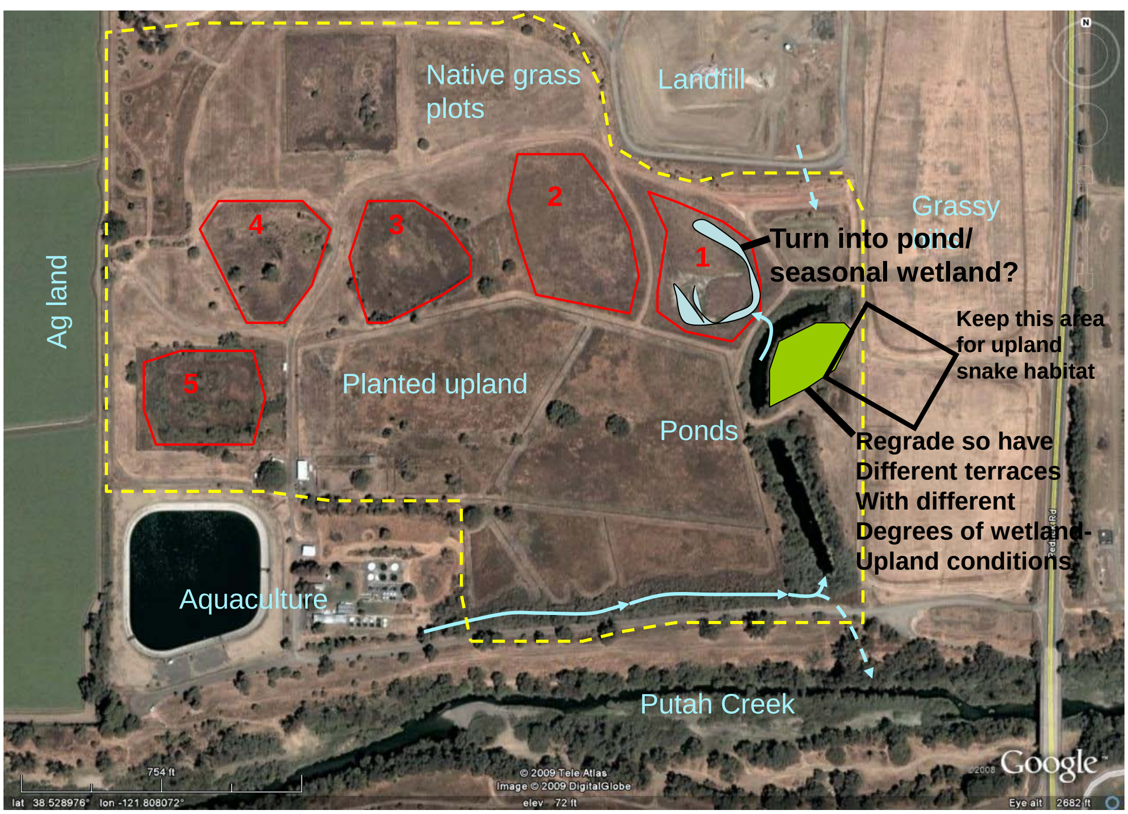
Basin 5

Project synthesis
In order to accommodate all of the individual goals/species of focus during the class (see table of contents, and individual reports for full information), the following plans were designed to balance these goals:

Constructed marshes/ponds
The ponds/constructed marshes are the most unique features on site in terms of key habitat for some species of concern, particularly the giant garter snake and the western pond turtle.
Key management priorities for these areas include: (see map below)
For the upper (northern) pond:

- remove exotics (especially yellow flag iris) and replace with herbaceous natives like bulrush and sedges in the wetter regions, which is important for garter snakes and the white-tailed kites.
- on the east side (towards the landfill), grade the bank so that there are terraces differeing in levels of inundation—this will allow for a gradient of native habitat types (e.g. bulrushes and sedges in the wetland, *Leymus* and *Hordeum* in mid-terrace, and upland species like *Bromus carinatus* in upland areas.
- provide basking sites (in water and at water's edge) for western pond turtle and giant garter snake. Ensure that snakes have access to higher elevation sites (e.g. landfill) in close proximity to ponds, during floods. (Road west of the ponds can flood, so that is inappropriate habitat, focus on east side of ponds).
- must avoid grazing, mowing, and groundwork on the eastern side of the ponds during the giant garter snake's inactive season (November through February).

Map detailing plans for constructed ponds/freshwater marshes



For the southern pond:

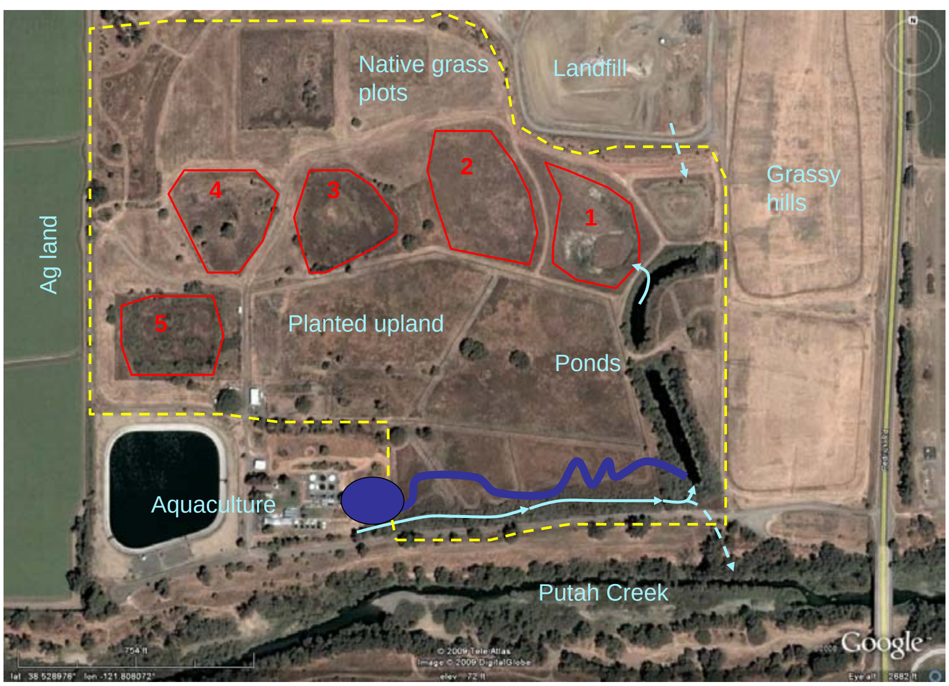
- Keep this area woody- provides important sites for birds and carbon sequestration.
- Manage the invaders around the ponds- but only gradually take out the woody invaders to minimize microclimate impacts. Once woody natives around the pond are well established, take out the woody invaders.

If more ponds are desired for habitat, the current small wetland in basin 1 will be the most promising. It has standing water in the rainy season, and this remains in small sections as the basin dries out in the spring (see map above). This basin will need to be tested for how well it would hold water on a larger scale if this is desired.

Riparian/stream habitat

The managers are considering moving the "stream" (effluent from the aquaculture facility) further north to expand riparian habitat. This would be improved by a few key considerations (see map below):

- allowing the stream to meander more
- if possible, develop a retention pond near the aquaculture facility, and use this to allow for period flood events (this also provides the benefit of providing a water source in case of a fire). If this is not possible, there will be occasional needs to replant the woody species, since there will be lack of conditions necessary for regeneration.
-
- willows will likely self-recruit to this area (as they are doing around the current stream area currently). Also plant oaks and elderberries. The establishment of these woody species may require tree shelters (vs. deer and other browsers), and some drip irrigation may be temporarily needed as these woody species establish deep enough roots to tap into the water table.
- weeds will be an important consideration—Himalayan blackberry and Italian wildrye are particularly of concern. Dense stands of the native grass *Leymus triticoides* could also develop and inhibit the establishment of woody natives.
- if more riparian vegetation is desirable, basins 3 and 4 currently have some riparian vegetation in them. It is not clear if this is due to historic conditions (legacy of when the ponds were actively filled with pumped water, and when they gradually dried out after this was ceased), or if their currently hydrology will sustain regeneration. More in-depth looks of hydrology and water table depth with season would be important next steps to take.



Upland grassland habitats

- because mustards don't respond to grazing/fire removal strategies well, it is best to start by eradicating these species (with solarization, which also kills other species in the area)
- Yellow starthistle will require burning/mowing in June/July. Most other weeds are likely to be controlled with a late March/April event (grazing, mowing, fire) to kill off plants before seedset (e.g. ripgut, ryegrass)—this timing is unlikely to have large negative effects on most native herbaceous species.
- to actively manage for forbs, it will be necessary to annual create disturbances/openings for them to emerge from grass stands (e.g. gopher disturbances, grazing, fire). Do not expect to see forbs every year, their populations vary naturally. Seed bank should be tested for current potential species on site—which can remain "hidden" in the seedbank for many years.

Habitat types overview

Under which conditions do native forbs and perennial bunchgrasses exist?

Marguerite Mauritz

A. Justification:

The goal of this project is to restore a diverse community containing both perennial grasses and native forbs. The site is located within the UC Davis Putah Creek Riparian Reserve and forms part of the larger Lower Putah Creek Coordinating Committee (LPCCC) initiative to restore and maintain natural habitat provided by Putah Creek from Monticello Dam to Yolo Bypass. Only 2% of grasslands in the Central Valley remain as intact native vegetation (Lulow 2008) and many native annual forbs are listed by the California Native Plant Society (CNPS) as rare and endangered. Native perennial grass and forb mixtures increase biodiversity which can reduce invasibility (Brown and Bugg 2001), provide valuable forage (Lulow 2008) and support a wide diversity of native insects and birds (www.xerces.org). For many years restoration of California grasslands has focused on relatively species poor native perennial bunchgrass communities. Recently this focus has shifted to maximise the benefits derived from including forbs in restored communities.

Losses of native forbs and grasses are largely due to development and poor management practices leading to the spread of invasives. High levels of competition from invasive species and low native seed pools make natural regeneration unlikely (Seabloom et al. 2003). Restoration projects therefore play an important role in assisting the establishment of native plant and animal communities. The goal of this project is to maximise diversity by establishing a mosaic of perennial grasses and forbs across the site. Appropriate management practices are often site specific and vary in their success. Research on restoration techniques on how to best establish a mixed community of perennial grasses and annual forbs is lacking. The success of methods employed will contribute to a regional understanding of 'best management' for restoring mixed perennial and forb communities.

B. Background:

I. Historic distributions and evidence for prevalence of forbs

Since the 1920's it has been the belief of ecologists that pre-European grasslands in the Central Valley were dominated by bunchgrasses. Although counter-evidence existed even then, the idea that forbs were an abundant and widespread component of grasslands has recently been revived (Hamilton 1997). It is believed that heavy grazing and a number of drought years caused the large-scale degradation of native grasslands and spread of invasive annual grasses by the 1800's. The bunchgrass-grazing hypothesis contends that *Nassella* spp. once dominated grasslands in the central valley of California but that grazing reduced the prevalence of this and other native bunchgrasses. As a result exotic annual grasses replaced native bunchgrasses. The best baseline data for historic plant distributions comes from William Henry Brewer's state survey which was not conducted until 1860. By this time many invasives were already wide-spread and drought had diminished flowering forb populations. In 1920 and 1934 Clements, a prominent scientist, argued that existing *Nassella* spp. patches were relicts of the once dominant vegetation. He based many of his ideas on observations of *Nassella* spp. in what he believed were unburned and ungrazed, undisturbed, habitats along fenced railway rights-of-way. Clements' evidence was strongly influenced by his confusion of *Nassella* spp. with another grass presumed to extend along the U.S. West Coast, into New Mexico, Texas and South America. Clements' bunchgrass-grazing hypothesis quickly became incorporated in scientific publications, government documents and popular literature. Dissenting opinions never had the chance to gain a foothold (Hamilton 1997). The dominance of bunchgrasses is however inconsistent with a centuries worth of historical records from the land expedition up the Californian coast led by the Spanish Juan Bautista de Anza in 1769 to the arrival of explorers such as John Muir in the 1860's. Their accounts tell tales of wildflowers carpeting valleys and hillsides (Minnich 2008). Records of bunchgrasses do exist but they describe coastal, riparian , Coast Range and foothill sites. More modern distribution maps from the 1940's show perennial bunchgrasses to be present in areas with at least 200mm annual precipitation (Wester 1981). Supporters of the bunchgrass-grazing hypothesis believe that heavy grazing led to the dominance of invasive annual grasses because the native Californian vegetation was not adapted to the grazing intensity of European cattle herds. The native animals that were widespread in California prior to European settlement speak to the contrary, that the vegetation is adapted to disturbance. California has always supported large grazing populations of mega- and mesofauna such as bears, elk, pronghorn antelope and a variety of rodents. Populations of burrowing and burrow-dependent animals such as voles, gophers and burrowing owls cause heavy soil disturbance. This lends further evidence to the case for annual forb rather than *Nassella* spp. or other bunchgrass dominance since annual forbs are better adapted to disturbance than perennial bunchgrasses (Schiffman 2000). In the absence of grazing few areas have shown recovery to native species composition which has lead to the suggestion that many native species are also seed limited (Seabloom et al. 2003). The historic disturbance regime implies that if carefully controlled grazing is an appropriate management technique (Hayes and Holl 2003).

Several ecologists now believe that forbs were the largest annual component of native CA grasslands and comprised the majority of their diversity; however many of these forbs are now rare (Lulow 2008, Minnich 2008). Forbs increase biodiveristy, are important for pollinators and can provide valuable forage (eg: native clover species) (Lulow 2008). Thus attention has shifted from creating grasslands to creating a mosaic of grasses and forbs. Attempts to establish forbs have met logistic challenges. A common management technique in native grassland restoration is the application of broadleaf herbicides to reduce non-native competition with native grasses. However, where forb diversity is part of the restoration goal broadleaf herbicides are not an appropriate management tool because they kill non-native as well as native forbs (Lulow 2008). Given current evidence of once more extensive forb populations it has been suggested that calling grasslands prairies would be more appropriate (Schiffman 2000) . While this may seem like a semantic detail, word choice can influence our perceptions, expectations and management decisions.

II. Conditions for bunchgrass vs. forb establishment

It is unlikely a single perennial bunchgrass would have dominated the Central Valley of California given the variable precipitation regimes and soil types. Perennial grasses may have persisted in wetter areas, more fertile soils of higher elevation and coastal sites. In drier, less fertile soils the annual component increases (Hamilton 1997). Forbs are able to establish a seed bank which allows them to persist when conditions are unfavourable (eg: low rainfall or high competition) and germinate in more favourable years. Appropriate germination cues are important. Volume and the timing of rain events as well as soil and air temperature play an important role in forb germination (Levine et al. 2008). In the past forbs were usually associated with high rainfall years. Unfortunately consecutive high rainfall years are favourable to invasive grasses as well as native forbs. Rapid grass growth causes strong competition with native forbs and the accumulation of thatch reduces light required for forb growth (Dyer and Rice 1999). Native forbs may therefore grow more vigorously when a favourable year follows a dry, unfavourable year during which grasses did not grow (Levine and Rees 2004). Forb growth must however be frequent enough to allow replenishment of the soil seed bank. Increasing annual invasive grass competition has decreased the window of time during which forbs grow and flower to one or two rain years following a period of drought. This has reduced seed banks (Minnich 2008). The availability of suitable microsites and sufficient seed volumes both play a role in successful establishment of native forbs (Seabloom et al. 2003, Moore 2009). Environmental fluctuation can promote dynamic coexistence when propagule supplies are adequate. In semi-arid systems extreme climates create patterns of high primary productivity and litter accumulation in wet years followed by fire in dry years. This results in dramatic shifts between desert-like and vegetated states (Holmgren et al. 2006). The vegetation of the Central Valley is likely to fluctuate between years of greater grass or forb abundance depending on climatic conditions and grazing pressure. These factors can interact to form complex patterns of community composition.

III. Current Restoration Practices

Given high levels of variability it is important that restoration techniques appropriate to the climate regime of the site are selected. Methods which are successful in one area may not be broadly applicable to all areas even if the suite of species to be restored is similar (Hayes and Holl 2003). Currently the most common vegetation restoration practices in California include planting and seeding of native species, herbicide application, burning and grazing. However the timing and intensity at which these should be applied are an area of active research and results are often site or region specific (DiTomaso 2000). Timing of management will also vary between years and among sites depending largely on precipitation patterns. Particularly any invasive annual grass control based on the phenology of the invasive, such as reducing seed production, will differ based on exact timing of when the grasses flower and set seed (Meyer and Schiffman 1999). Invasive annual grasses are thought to compete with native perennials for light (Dyer and Rice 1999). Litter removal either through burning, grazing or mowing stimulates perennial grass and forb growth. Spring grazing or burning treatments have been applied to destroy invasive annual grass seeds and reduce grass density in subsequent years (Meyer and Schiffman 1999). Burning and grazing can stimulate tillering, seed production and division of bunchgrasses (Menke 1992). The current shift in focus to native annual forb restoration adds additional complexity because broadleaf herbicides are used to control invasive forbs without killing the native grasses (Lulow 2008). A two-stage approach may be appropriate to establish perennial grasses and annual forbs. Rather than simultaneously growing forbs and grasses, forbs can be seeded or planted into a background of established grasses (Brown and Bugg 2001). High density and high diversity seed mixes can also increase the success of forb establishment (Sheley and Half 2006). Forbs require disturbance so ensuring some bare ground is present with low levels of disturbance could facilitate their emergence (Brown and Bugg 2001). Many native perennial bunchgrasses favour well drained soils and would thus be best established in areas where soils are better drained (Heady 1977). Forbs are desirable because they attract native insects and have aesthetic value for humans (Brown and Bugg 2001).

Increased biodiversity increases the resistance of a community to invasion (Kennedy et al. 2002). Many invasive forbs could be displaced by restoring the native forb component (Brown and Bugg 2001).

Given the high degree of uncertainty and the paucity of research on establishing mixed bunchgrass and forb communities the best approach is going to be an adaptive management plan. This will allow a variety of methods to be assessed and increase the chances of finding successful techniques. The nature of forbs is that they germinate and grow variably depending on site conditions. An appropriate goal may therefore be to establish a seed bank and appropriate disturbance regime so that when conditions are favourable the forbs will emerge.

Detailed restoration plan

The goal of this restoration plan is to restore a species-diverse native CA prairie with a variety of perennial bunchgrasses and forbs.

Two complementary goals:

- Establish a mosaic of coexisting forbs and grasses (see appendix for species specific requirements)
- Establish a forb seed bank

Due to the highly variable nature of forb germination establishing a complement of grass and forb species requires both a long term and short term approach (Levine et al. 2008). Establishing and managing a diverse community, it would be unreasonable to expect the same species composition each year. The aim should be to create a spatially and temporally variable community which persists across the whole site because individual components may not remain constant. Establishing a seed bank will be important for this goal, especially in the case of forbs which may only emerge in years with suitable weather conditions, a factor beyond the control of managers.

Factors necessary for establishing a diverse community containing forbs and perennial grasses:

- Current practice is to establish perennial grasses first to allow herbicide application if necessary, sow forbs later
- Heterogeneity of environment:
    - Need disturbance such as rodent activity and fire
    - Need patches of thatch free, bare soil
    - Need open areas
    - Variety of drained/undrained soil
- Seeding at higher density may be better than lower density for forbs
- Diversity and high density of cover may reduce invasion by non-natives
- Herbivory either naturally by rodents or with managed grazers will prevent grass dominance and create conditions suitable for forbs

There is a limited body of research on restoring areas with both grasses and forbs. Current practice is to apply pre-emergent and broad-leaf herbicides through the growing season which kills native forbs along with the non-native forbs being targeted (Lulow 2008). However there are a variety of techniques which have been used successfully in mixed grass and forb restoration. Each study focuses on different groups of species so it is unknown how well any one of the techniques will promote the species we are trying to restore. The requirements of individual species will overlap in some respects and differ in others; a variety of techniques may be necessary to maximise diversity. Many of the studies have been conducted in areas around the Central Valley and the techniques are therefore applicable to this site. Management options are summarised in the following table:

Management technique	**Application**	**Advantages**	**Disadvantages**	**Reference**
Livestock	Winter	Can be low	Native perennial	(Hayes

Grazing	season, spring grazing may be possible but was not tested in this study	maintenance if timing and intensity are well managed, increases native annual forbs and perennial grasses, prevents dominance of grasses	forbs reduced, non-native perennial forbs increased, can be expensive, may be more effective on a large scale and on a longer time scale, compaction can cause problems	and Holl 2003) **this study was conducted in a coastal pairie over a large scale**
Broadleaf herbicide: 2,4 D	Early spring	Effective at removing non-natives, relatively low cost, low intensity, careful timing can be effective	Toxicity concerns, may also reduce native populations	(Lulow 2008)
Clipping	Spring when non-native growth rates are maximum, prior to soil drying, winter clipping was not tested here	Simulates grazing but can be more tightly controlled than grazers, no issues with selective grazing or toxicity of plants, can be effective without herbicide application	Labor intensive	(Lulow 2008)
Litter removal	October	Relatively low disturbance with few side-effects	Labor intensive, may also increase non-native abundance (eg. *Erodium* spp), not always effective	(Talbot et al. 1939, Meyer and Schiffman 1999)
Fire	Late spring	Bare ground enhances forb establishment	Concerns and logistics with controlled burns	(Meyer and Schiffman 1999)
Direct seeding	Winter	Cheaper than transplants, seeds mixed with potting soil makes distribution easier and more even	Variable success	(Brown and Bugg 2001)
Container transplants	Winter	Higher plant survival	Expensive	(Brown and Bugg 2001)
Irrigation	Spring and summer	Higher plant survival	Additional cost	(Sheley and Half 2006)

Restoration Plan:

Site preparation (Spring with possible late fall repetition):

Heavy grazing coupled with herbicide application to remove non-native grasses and forbs. Grazing with sheep or goats will reduce compaction. Where soil is compact tilling may be necessary prior to planting.

Alternative: burn site to remove non-native vegetation

Year 1:

Following preparation either drill seed or plug plant perennial grasses and apply broadleaf herbicide later in spring to remove non-native forbs.

The upland area is a good area to target for drill seeding because it is large and flat. Basins may require plug planting or hand seeding.

Year 2:

Graze early in spring to reduce annual grass cover and seed bank (if these have reestablished), if grazing is not possible or compaction is problematic mowing is also an option, some litter can be left to suppress invasives but remove litter in patches because forbs require litter removal

- Strategically seed or plant areas that may be more suitable for individual species, either broadcast sow or plant seeds and protect forbs from herbivory with tubes
- In areas where invasive forbs are particularly problematic grazing or herbicide application could be focused rather than attempting to seed or plant native forbs, spot herbicide application is effective for smaller invasive forb patches
- Where grasses are well established plant or seed forbs between grass rows or patches
- Based on soil conditions the following assemblages are appropriate:
    - Basin interior: *A. fascicularis, H. brachyantherum, L. triticoides, E. californica, B. carinatus*
    - Basin banks: *V. microstachys, B. carinatus, Grindelia, Lupinus, E. californica*

Year 3:

Graze or mow early in spring and reseed forbs to increase density, as above patchy litter removal can promote forb establishment but also reduce invasive forbs

Long-term:

Once Oaks are established and large grasses should be sown under the canopy, the same applies to other riparian trees.

Grazing every 2-3 years to allow natives to grow but prevent dominance and be able to control invasives and **burning** may be necessary for long term **maintenance** to prevent dominance of few species.

Monitoring will be required each year in the initial phases, at least the first three years and then periodically every 2-3 years. Depending on resources the minimum monitoring should be vegetation surveys.

Measures of success:

The overall target and measure of success for this restoration should be biodiversity. Monitoring will determine what the diversity of species is across the entire site. Both total species number (richness) and the relative numbers and distribution of species (evenness) should be considered. Forbs are annual and do not germinate every year. Temporal diversity is therefore an important component. Measuring success in terms of diversity also gives some leeway with regard to invasive species control. Invasive populations can actually contribute to diversity as long as they do not dominate. The goal should be to have a mix of specie to provide habitat, pollinator services, carbon sequestration, fire reduction and aesthetic appeal.

Trade-offs and considerations:

- The main trade-off is the sensitivity of native and invasive forbs to herbicides. However Brown and Bugg (2001) established forbs without herbicide application by taking advantage of well established perennial grasses, planting and seeding forbs in between grasses.
- There are a number of trade-offs between timing and type of invasive control based on different sensitivities of native species. This information is summarised in the appendix.
- Grass and forb prairies provide food for and benefit from disturbance by rodents, this in turn benefits raptors.
- Grasses and forbs will not interfere with pond turtle habitat. *L. triticoides* or *H. brachyantherum* are probably the most appropriate species for the pond periphery.
- Grass and forb prairie is most suited to the upland area, in and around basins. Therefore this target will not interfere with establishing riparian trees. Once trees are established grasses and forbs can be planted under trees. The shade will favour slightly different species assemblages compared to the open, full sun basin areas. Thus tree and prairie goals are complementary in the long term.
- Monitoring will allow management to be adjusted from year to year. Where invasives are particularly dense or difficult to remove control efforts can be focused to contain patches. Small invasive patches can be treated individually to reduce localised competition. In areas where compaction is a problem herbicide treatment may be preferable to grazing.
- As much as possible herbicide treatment should be limited due to general negative environmental impacts and the site's proximity to water. Localised application with a backpack sprayer ensures that herbicides are not applied in excess.

Research potential:

- Is it better to sow a mix or better to establish individual patches and allow mixing to take place naturally as seeds disperse over time?
- Test possibility of controlling non-native populations across the site on a patch-by-patch basis.
- Test timing of herbicide application to suppress non-native forbs but not native forbs
- Test type of disturbance – fire, grazing, tilling/soil disturbing animals
- Test timing and pattern of disturbance regime
- Compare seeding and transplanting success for forbs and grasses
- Monitor seed production, recruitment and self-sustainability of plant population
- Measure effect of rodent herbivory
- Are there emerging patterns of higher and lower success across the site and dominance of certain species? Is this due to soil conditions, herbivory, moisture?

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Restoration of riparian habitat

Parts I and II, final version – ENH 160 – 4 June 2009

Evan Wolf

A. Background and justification

The goal of this proposal is to identify the potential benefits, in ecologic and human value terms, of restoring riparian habitat. The central role that water plays in shaping river corridors makes riparian habitat restoration particularly important in the western US, where water resources are extensively used for agriculture and urban needs. Largely due to the availability of water and nutrients, riparian areas support rich and abundant plant and animal life. At least 50 amphibian and reptile species occur in lowland riparian systems. Many are permanent residents, others are transient or temporal visitors (Brode and Bury 1984). In one study conducted on the Sacramento River, 147 bird species were recorded as nesters or winter visitants (Laymon 1984). Additionally, 55 species of mammals are known to use California's Central Valley riparian communities (Trapp et al. 1984).

Of the estimated 4,000 km^2 of riparian forest that the Central Valley used to contain, 416 km^2 exist today (Richards and Chirman 1994), with only about 40 km^2 in pristine, functional condition (Ricketts et al. 1999). Due to the massive loss of riparian habitat over the last 250 years, a reasonable assumption is that riparian areas used to support many more species than they currently do. In addition to habitat, functioning riparian ecosystems provide numerous ecosystem services such as flood mitigation, erosion prevention, sediment trapping, nutrient (e.g. carbon, nitrogen, phosphorus) and pollutant cycling and storage, and recreation.

California presents an excellent example of how intensive human water use has dramatically altered the natural flow regime and the riparian habitat that depends on it. Within the State 79% of the water that passes through a delivery system is used for agriculture, with the remaining 21% going to cities and towns (California Department of Water Resources 2009). Many channels are prevented from flooding by the emplacement of levees, banks are armored to prevent erosion, and channels are straightened and narrowed to convey water more quickly. In addition, logging, grazing, and road building all directly impact riparian habitat, often completely eliminating it along a reach of river. By far the most intensive agricultural region is the Central Valley, much of which historically was seasonally flooded wetlands fed by the same water that is now impounded behind dams and piped to farms throughout the year. The quantity and timing of flow has been dramatically altered by dams, diversions, and levees, resulting in major changes to the riparian ecosystems that rely on annual floods.

The extent of large and small scale impacts that rivers have suffered indicates that they should be a target of conservation and restoration efforts. Within the United States the Clean Water Act of 1972 regulates many of the impacts described above that have the potential to physically alter river channels, flow regimes, and water quality. Until this last decade much of the enforcement of the Clean Water Act focused on water quality standards and “point source” pollution. However, the scope of the Act has been more broadly applied recently to include “non-point source” pollution, such as agricultural runoff, and to protect the physical and biological integrity of rivers as well. The US Army Corps of Engineers requires that all activities that have the potential to negatively impact a river or wetland be evaluated through the 404 permit system (EPA 2009). All significant impacts are required to be minimized or mitigated. These regulations significantly decreased the loss of wetlands, but the goal of “no net loss” set out in 1989 by President George H.W. Bush has not yet been achieved. One main reason for this is that there is not yet a comprehensive wetland survey of sufficient detail to determine the status of the nation’s wetlands, of which riparian zones are a major component (National Wildlife Foundation 2009). Many small or skinny wetlands less than 1 to 3 acres in size are missed by the currently used National Wetland Inventory, and many riparian corridors fall into this category.

Riparian areas often display ambiguous soil, hydrologic, and vegetation characteristics with respect to the accepted standards for wetland classification. Because the floodplains are often only saturated during flood events, which are episodic, energetic, and short lived, the soils don’t always show hydric characteristics indicative of the saturation. Compounding this problem is the fact that most rivers in the US no longer experience a natural flood cycle due to hydrologic modification. Also, most riparian plants are not definitive wetland indicators, another key component of wetland classification for purposes of regulatory status. Many riparian plant species require flood processes for establishment, but once they become established they can persist outside of riparian zones.

Some of the gaps in government regulations are filled by numerous private, non-profit, and government programs whose specific aim is to restore degraded wetlands and riparian areas. Organizations such as Ducks Unlimited and the National Audubon Society target wetland and riparian restoration to create bird habitat. Many government agencies provide grants for the improvement of riparian and wetland ecosystems for the purpose of improving water quality, natural water storage, and recreation opportunities. In California the Sierra Nevada Conservancy and Coastal Conservancy are large tax-payer funded measures with strong riparian restoration components. Nationally the National Fish and Wildlife Foundation is a publicly funded non-profit organization that targets many types of habitat restoration, including riparian areas.

The opportunities and benefits of riparian habitat restoration are many, and given the ever increasing expansion of human impacts, are critical now and will become more important through time.

B. Literature Review

Riparian ecosystems are formed and maintained by the hydrologic and geomorphic processes of rivers. The definition of riparian zone can be complex, due to the complex nature of flood frequency and subsurface flow, but in general the riparian zone is the area that encompasses the river channel and its current or potential floodplain (Griggs 2008). In the western U.S. many riparian plant communities are structured primarily by woody shrubs and trees. Within the Central Valley of California the dominant canopy trees are cottonwood (*Populus fremontii*), California sycamore (*Plantnus racemosa*) and valley oak (*Quercus lobata*). The sub-canopy is composed of white alder (*Alnus rhombifolia*), boxelder (*Acer negudo*) and Oregon ash (*Fraxinus latifolia*). Typical understory shrub layer plants include wild grape (*Vitis californica*), wild rose (*Rosa californica*), California blackberry (*Rubus ursinus*), blue elderberry (*Sambucus mexicana*), poison oak (*Toxicodenron diversilobum*), buttonbrush (*Cephalanthus occidentalis*), and willows (*Salix* spp.). The herbaceous layer is variable but commonly contains sedges (*Carex* spp.), rushes (*Juncus* spp.), grasses (Poaceae), miner's lettuce (*Montia* spp.), Douglas' sagewort (*Artemisia douglasiana*), poison-hemlock (*Conium maculatum*), and hoary nettle (*Urtica dioica*) (Grenfell Jr. 1988).

Many of these plants possess physiological and life history traits that are adapted to the physical processes of rivers. For willows and cottonwoods, seed dispersal is timed to coincide with receding flood waters in spring (Cooper et al. 2003), broken stems and twigs are able to root and form new individuals if buried in flood sediment (Kindschy 1989, Cottrell 1995), and flooded, anoxic soil conditions that are lethal to many plants can be tolerated, but drought tolerance is low (Kozlowski 1984, Armstrong et al. 1991).

Woody shrubs and trees form the basic structure of riparian habitat. The vertical layering of the multi-tied canopy provides living space, feeding areas, shade, and shelter to numerous trophic levels and diverse guilds of animals (Tockner and Ward 1999). The woody plants also enhance many ecosystem processes that are critical to the stability of riparian zones: Their sturdy upright stems and strong perennial roots stabilize stream banks, enhance sediment deposition during floods, maintain stream water quality, and they contribute coarse woody debris and fine organic matter to streams (Naiman and Decamps 1997). This positive feedback between hydrologic processes that support woody plant establishment, and woody plants that allow the creation and maintenance of fluvial geomorphic features produces a dynamically stable riparian zone.

Riparian ecosystems are both valuable from an ecologic and human societal standpoint, and are highly modified by human activity, which makes them important targets for conservation and restoration. Because of the positive feedbacks between the physical processes of river flow and sedimentation, and the riparian plant community, it is critical to consider both the hydrology of the river and the needs of the woody floodplain species. One without the other is unlikely to succeed. There is evidence that significant changes to the geomorphology and hydrology of a river will decouple the positive and stabilizing relationship between the river and the riparian vegetation, resulting in an alternate stable state that will not recover without restoration intervention (Wolf et al. 2007). In addition, restoration projects that have attempted to imprint specific channel morphologies on rivers have often failed due, in part, to the failure to consider the role of riparian vegetation in determining channel form (Kondolf 2006). Any restoration or creation of riparian habitat needs to consider the linkages between the physical processes of river flow and the woody riparian shrubs and trees that will form the structure of the riparian plant community.

There is ample evidence to show that for any river restoration project establishing an appropriate hydrologic regime is critical for maintaining natural riparian vegetation types (Jansson et al. 2000), for maintaining floodplain wetlands (Stevens et al. 1995), for managing plant invasions (Décamps et al. 1995), and for providing the necessary disturbance to allow for woody plant establishment (Cooper et al. 2003, Richter and Richter 2000). What is less well known is how much influence vegetation has on stream morphology and flow dynamics. Several studies indicate that the influence of vegetation can be large (Birken and Cooper 2006, Micheli and Kirchner 2002), and that the paradigm of restoring the physical processes first and establishing vegetation second may miss the important feedback of the vegetation on the hydrology and geomorphology of the river. More experiments and restoration monitoring will be needed to work out the feedbacks between riparian vegetation and channel hydrology and geomorphology in different settings.

Part II

Goals

The primary goal outlined in this proposal is to establish a riparian zone that provides habitat to a diverse suite of animals. Several smaller goals are required in order to achieve this main goal.

Working backwards from the main target, the critical requirement for high-value riparian habitat is to establish a self-sustaining, diverse riparian plant community that includes a multi-tiered canopy of tree, shrub, and herb layers. A precondition for the establishment and persistence of riparian vegetation is a hydrologic regime that provides the quantity and timing of water that is suitable for the desired vegetation. This typically includes a spring flood cycle followed by a slow decline in water level throughout the summer growing season. Since vegetation success is contingent on this water cycle, restoring the hydrologic process is the first goal that must be met before the primary goal of establishing vegetation can occur. Finally, once the goals of hydrology and vegetation have been achieved, the main goal of providing habitat can be realized.

Some of the habitat value of riparian vegetation is only gained when the trees and shrubs reach full maturity. Even though many riparian species are fast growing, it can still take 25 to 30 years for cottonwoods to reach full stature and more than 75 years for valley oak (Grenfell Jr. 1988). Shrubs such as willows, wild rose, and elderberry mature more quickly and provide maximal habitat benefit within about 5 years of planting. Given this time frame for structural maturation, habitat quality will improve slowly through time, with initial conditions providing little or no habitat benefit for most animals. For example, raptors require tall perches, often preferring tall dead snags, and formation of dead trees takes an entire generation. Therefore, the ultimate goal of restoring animal habitat may not be reached for several decades, so a monitoring scheme and performance measures need to be matched to this time scale. The preceding goals of restoring the hydrologic regime and establishing a persistent vegetation community can be achieved and their success evaluated after the first year and in subsequent years. However, natural floods occur with significant interannual variability. Because seedling establishment requires these floods, it too varies year to year. Therefore, the evaluation of success of the hydrologic goal should be: 1) did inundation of the floodplain occur given that there was sufficient precipitation to cause a flood, and 2) did the water table drop <2.5 cm per day in areas where cottonwoods are hoped to establish, or <1 cm per day for willows? Whether or not sufficient precipitation fell to cause a natural flood can be evaluated by examining current and historical stream data from nearby similar creeks that experience natural flow regimes and comparing the extent to which they flooded. The vegetation establishment goal can be evaluated in the context of the hydrologic goal: given that a flood occurred and water table declines were appropriate, did seedlings sprout and survive through the summer? For the goal of establishing a persistent riparian plant community, success may take longer than a year to determine. However, many of the riparian shrubs and herbs will display vegetative and sexual reproduction in the first year following planting if the hydrologic goals have been met (Griggs 2008).

A critical consideration is whether the restoration site has the capability to meet all of the hydrologic and vegetation goals that will lead to the ultimate habitat goal. Often the most constraining feature of a site is the ability to restore the flood cycle. As is noted above, this process is critical to the establishment of many riparian plants, and thus the long term natural persistence of the riparian plant community. However, by planting seedlings or saplings, the establishment phase can be bypassed, and riparian vegetation can be restored to sites with suitable water table depths, even if the water level doesn't fluctuate or flood. Once planted, a riparian restoration at a site with a static water level will mature and produce full statured plants that will provide the desired habitat. However, although some species will be able to clonally reproduce (e.g. *Salix exigua*, present on site along the aquaculture outflow) many require a flood disturbance that creates bare, moist substrate for seedling establishment, so these plants will only persist for the planted generation. Therefore, to maintain a diversity of age classes at the site, periodic plantings would be required.

Restoration Plan

The ideal restoration plan, from the perspective of reestablishing a completely self-sustaining riparian habitat, would be to restore the full range of hydrologic processes to the site, including flood cycles. In many cases this would require the removal of dams, diversion, levees, and other major engineered structures. The benefit to this approach would be that the riparian vegetation would only have to be established once through planting, and then the flood cycles would provide the necessary disturbance to allow for further recruitment. In addition, a fully established riparian plant community would dissipate some of the flood energy, allow for sediment deposition, stabilize stream banks, and generally reduce the need for the engineered structures that were required to control the river in the first place. This feedback between the hydrologic processes and the riparian vegetation is dynamically stable, and would require no further management of the site to provide ideal riparian habitat.

However, the up-front cost of removing major hydrologic control structures, and the opposition for those who benefit from them, is likely to preclude a full restoration of natural flood cycles to the site. Therefore, the next best alternative is to use the control structures to create floods on site. This would be most feasible in Basin 1, where a screw gate controls the water entering the basin, and at the outlet stream from the aquaculture facility. These two locations present slightly different opportunities and challenges.

Water released into basin 1 would fill it like a bath tub and carry little or no sediment. In addition it would have no velocity to remove litter or scour the ground surface, and so it would create moist, but not bare substrate, and would be unsuitable for seedling establishment of many flood adapted plant species. This problem could be overcome by creating a physical disturbance to the ground surface just prior to the controlled flooding. Raking or scarifying the soil surface to remove litter would simulate flow scour. Another alternative would be to burn the litter layer off using a prescribed fire, exposing bare soil. There is evidence that burning of a floodplain can provide a necessary disturbance to allow for flood adapted willow species to establish new seedlings (Wolf et al. 2007).

The combined physical disturbance and calm flooding should be timed to coincide with the natural flood peak, which in the Central Valley is late April. Maintenance of year-round surface water within the basin would allow for the design of different zones of riparian vegetation which would be determined by their elevation above the water level. The surface water level would have to be maintained by frequent additions of water, as water in the basin would be lost to evaporation, transpiration, and infiltration. The infiltration will create a subsurface water table that slopes down away from the pond edge in cross section.

Currently, the aquaculture outlet stream flows at a constant rate in a small, straight channel lined with the clonal willow, *Salix exigua*. In order to increase the width of the riparian zone and stop willows from encroaching on the adjacent road, the channel should be moved north, away from the road, and re-dug with meanders. In order to allow for the possibility of flood releases, the re-dug meandering channel should be inset within a broader floodplain terrace, which itself should be approximately a foot below the surrounding upland and wide enough to accommodate the volume of water released as a controlled flood. The controlled flood release could be achieved by building a holding pond at the head of the stream with an outlet capable of releasing the pond water rapidly as a flood pulse. The release should be large enough to inundate the entire floodplain and have enough flow velocity to produce some scour and sediment transport on the floodplain surface. The release should be done in the late spring, to coincide with the seed release of non-clonal willows, cottonwoods, and other riparian species planted along the creek that depend on flood disturbance for seedling establishment.

The depth to the groundwater table at both basin 1 and the creek floodplain should be measured using hand augured monitoring wells. The depth to groundwater as one moves further from the permanent low water line will determine the type of vegetation that will be suitable for that zone. For the zone closest to the base level (not flood level), sedges, rushes, and freshwater marsh herbs would be appropriate. This zone would extend from a depth to groundwater of 0 to 40 cm. The next zone would be dominated by shrubs, primarily willow, but also alder and other shrubs and vines discussed above. This zone would extend across the area with a depth to groundwater of 40 to 120 cm. Finally, the third and highest zone will be planted with tress: cottonwood, sycamore, and valley oak, and an understory of elderberry, wild rose, and other species mentioned above. The depth to water table in this zone should range from 120 cm to 240 cm. Cottonwoods and sycamores prefer coarser soil texture, while valley oaks thrive in finer textured heavy soils (Griggs 2008).

The late April controlled flood should be conducted as follows: the basin and creek floodplain should be filled rapidly to the level that just inundates the highest (tree) riparian vegetation zone. The water level should be lowered back to the year-round base level over the next 3 to 5 days. It will probably be necessary to use additional water other than aquaculture effluent to achieve this duration of inundation in the creek channel. The saturated soils of the riparian zones should hold the soil water table up above the receding water level. To allow for the natural establishment of riparian plants from seed, the soil water table should not decline more than 2.5 cm per day following the flood peak for cottonwood seedlings, and no more than 1 cm per day to allow for willow establishment (Amlin and Rood 2002). This rate of decline will allow the plant roots to track the water table as it drops.

Seeds and cuttings for the initial planting should be obtained from the nearest natural riparian population that is available. The desirable species have been listed above. All woody species should be planted as saplings, sedges and rushes as seedlings, and understory herbs can be broadcast seeded.

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Fresh Water Wetlands

Andrew Gray

I – An Overview

Introduction

Several opportunities exist at the Putah Creek Reserve (PCR) for freshwater wetland restoration, some of which may prove to be highly beneficial in terms of ecosystem services such as key habitat for a wide array of animals as well as mitigation for other UC Davis development projects. Wetland habitats are some of the most threatened by development, with worldwide wetland losses estimated at 50% and the majority of remaining wetlands degraded (Dugan, 1993, Brinson and Malvarez, 2002). In California, the deterioration is very advanced – most estimates show greater than 90% loss of wetlands since the western occupation of California, with much of those losses due to economic development for agriculture, urbanization and water resource purposes (Dahle 1990, (Heimlich and Melanson, 1995). Recent changes in the socio-cultural valuation and understanding of wetlands in the U.S. have lead to increased levels of protection for these habitats, as well as legal mandates/ incentives for wetland restoration and creation (Heimlich et al., 1997). Wetlands are now thought of as key habitats with immense ecological importance for both endemic and transient organisms, as well as considerable economic value (Allen et al., 1992).

This chapter will begin by identifying the different kinds of wetlands that may be of importance at this site. We will then examine the major areas of concern when dealing with wetland restoration, namely:

- Geomorphology
- Hydrology
- Ecological Issues (relevant communities, invasive species, potentially dangerous vectors)
- Legal Considerations

Finally, a brief historical perspective on wetlands in California will precede a general synthesis.

Types of Freshwater Wetlands

The definition of what constitutes a wetland varies between professional communities within the United States and abroad. However, increased awareness of the ecological and hydrological value of wetlands in the later part of the 20^{th} century influenced the development of protective legislation in the U.S., which heightened the need for consistent language. The regulatory definitions most often used for site assessment in the US come from the U.S. Army Corps of Engineers and the Natural Resources Conservation Service (NRCS). Both definitions share three central components, which we will consider to be the defining elements of wetlands for the purposes of this document. Thus, to be considered a wetland, the plot must contain:

1) A predominance of hydric soils

2) Inundation or saturation by surface or ground water at a frequency and duration sufficient to support…

3) a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions.

(16 CFR 801(a)(16); 1985)

There are also many different methods of further subdividing wetlands on the basis of geomorphic, hydrologic and ecological characteristics. Beginning from broad, inter-paradigm classifications, only a handful of freshwater wetland types are relevant to this study due to the particularities of the PCR site:

- Riparian
- **Freshwater Marsh**
- **Vernal Pools**

Riparian habit is a large enough component of this site to merit a separate section in this report (see p…). Fresh water marshes are broadly defined as inland wetlands that are not tidally influenced and bear emergent macrophytes. *The area currently used to treat effluent from the aquaculture center falls under this general category.* Vernal pools are periodically wetted upland sites, generally meadows, positioned at a fluctuating water table/surface interface or, more commonly, underlain by substrate of a lower hydraulic conductivity which allows for prolonged retention of standing water/moisture relative to adjacent sites ((Keeley and Zedler, 1996). *The defunct ponds at the site may be considered as artificially induced vernal pools.*

Physical Considerations

The range of topography present at the PCR site underscores the importance of geomorphic setting when considering engineered wetland projects. As all wetlands must at least periodically possess an amount of moisture sufficient to saturate the substrate, the following physical factors essential to moisture regime are critical to wetland management plans and will be addressed in the context of vernal pools and freshwater marshes:

- Hydrologic Connectivity
- Substrate: Soils & Geology
- Geomorphology/Topography
- Climate

Hydrologic Connectivity

Freshwater wetlands may be classified from the perspective of water source. As moisture maintenance is critical to the success of wetland projects, defining a given site in this regard is the first step toward understanding how the wetland may be maintained. Of relevance to this project are wetlands with the following hydrologic drivers:

- *Precipitation*: perched catchments with shallow, depressional storage of rainfall and little or no groundwater to surface input (Fens, Vernal Pools)((Wacker and Kelly, 2004).

- *Groundwater*: breaks in topography, landscape depressions or changes in the aquifer which lead to the interface of groundwater or capillary zone (Bogs, Slope Wetlands Vernal Pools)(Brinson and Malvarez, 2002, Stein et al., 2004).
- *Surface water*: association with lake and river margins, periodic or continuous connectivity with channelized flow. (Riparian, Fresh Water Marshes)

Many studies have been conducted on the hydrology of wetlands, yet this area is still poorly understood due to often insurmountable difficulties in quantifying certain components of the water balance (Zedler and Kercher, 2005). Groundwater contributions or losses and evapo-transpiration rates in particular have been difficult to determine.

In the context of the **freshwater marsh** at this site, the water source is primarily artificial, originating as controlled effluent discharge from an aquaculture facility. Thus, the first hydrologic priority for the marsh is to understand the present and future discharge regime as per the aquaculture facility's operating plans.

Substrate: Soils & Geology

Wetland soils and underlying regolith play a crucial role in maintaining wet conditions, particularly in precipitation fed vernal pools where seasonal capture of rain is dependent upon slow release of depressional/soil storage to underlying strata (Wacker and Kelly, 2004). A wide range of soils may be present in wetlands, though they generally share features associated with prolonged or temporary saturation such as gleying and the accumulation of a high amount of organic matter. While physical characteristics of soils are critical components of wetland hydrology, these aspects along with chemical content are also essential to ecological structure. Wetland restorations may require addition or removal of nutrients to promote certain species or repress others (Callaway, 2001, Perry et al., 2004).

Topography

Likewise, site and surrounding topography play a large role in determining moisture regimes for most wetlands. Small changes in surface elevation may remove a site from groundwater connectivity. Slope geometry strongly influences the convergence or divergence of overland and subsurface flow of water for wetlands situated in coves, slopes or hollows (Stein et al., 2004, Hack and Goodlett, 1960, Osterkamp et al., 1995).

Climate

Ultimately climate may be the most important factor in wetland development, though often overlooked due to the differences in spatial and temporal scales in relation to other important factors. Changes in precipitation regime and solar energy input can change not only the amount of water entering a wetland from above, but also alter groundwater levels and surface water systems and change the evapo-transpiration of the system. This may be a particularly important consideration as the wetlands developed on this site will be supported in part by controlled additions of water that may be required for other services if our region becomes drier.

Ecology

- Readily dominated by invasive species, often to the point of monotypic stands (Zedler and Kercher, 2004)
- Timing of hydrologic regime plays a large complex role at the species, population and community level (de Szalay et al., 2003)
- Nutrient presence may be highly enriched or extremely poor, with availability issues due to anoxia and redox. chemistry

Freshwater wetland ecology spans a vast array of communities. Typical distinctions in the literature are made between nutrient enriched, highly productive wetlands and nutrient poor situations. From a very general standpoint, highly productive wetlands are often the least diverse in terms of flora, typified by the monotypic stands of emergent macrophytes such as Bulrush (*Schoenoplectus* *americanus*) and Cattails (*Typa spp*.) commonly found throughout freshwater marshes in California. Faunal diversity in such areas may be exceedingly high. The high potential for biomass production in these areas also allows the competitive advantages of rapidly growth and colonization to be asserted in the plant community. Thus, monotypic stands of native vegetation are commonly supplanted by monotypic stands of invasive vegetation in the U.S. and elsewhere (Zedler, 1996).

Vernal Pool habits, in contrast, are nutrient limited situations of high gradient moisture regime change throughout the yearly cycle (Bauder, 2005). California/West coast vernal pools are ephemeral from a seasonal standpoint, but are areas of recurrent saturation due to soil, geomorphic and geological characteristics (Rains et al., 2008). The edaphic vegetation assemblages that form on these sites are often limited in their dispersal to only vernal pools, and often only certain sub types of these land forms (Zedler, 2003). Thus, the degradation of these areas has lead to a threatened or endangered status for plants such as Colusa Grass (*Neostapfia colusana*) and Solano Grass (*Tuctoria mucronata*) **–** both of which come from genera commonly found in vernal pools, as well as the much studied Vernal Pool Fairy Shrimp (*Brachinecta lynchi*) and similar species. Much more work needs to be done to understand these delicate and imperiled habitats.

Ecosystem Services (General)
(Zedler and Kercher, 2005)

1. **Biodiversity**
   - ~ 50% of endagered spp. In US depend upon wetlands
   - Extreme productivity
2. **Water Quality**
   - Nutrient sink
   - Particulate removal
   - Pollutants
3. **Flood Abatement**
   - Decrease in flood “flashiness”:
   - Reduction of peak flows
   - Increase in delivery timing
4. **Carbon Management**
   - Extreme productivity
   - Sequestration with anoxic depositional zone

Legal Issues

Human created wetlands are specifically exempted from the language of the NRCS/Food Security Act (16 CFR 801(a)(16); 1985). Wetlands created as mitigation under the laws which followed the National Wetlands Policy Forum of 1987 become subject to the no net loss concept which mandated their construction since the early 1990s. However, the wetlands of interest for this project were created for research purposes, and are not subject to the no net loss rules. Thus, creation or maintenance of wetlands at the PCR site may be used to offset future disturbances of natural wetlands perpetrated by the University of California Davis.

Historical Perspective

The Great Central Valley of California, between the Coast and Sierra Mountain Ranges, once supported vast tracts of freshwater marshes and vernal pools (Mitsch and Gosselink, 2000, Heitmeyer et al., 1989). Although wetlands are somewhat ephemeral features, often extinguished in less than 10,000 years for a given land surface, the change in relative abundance of wetlands during modern times has progressed with a unique magnitude of rate and scale (Kelly, 1997). The deterioration of wetlands in the U.S. is only one natural disaster set within a larger framework of habitat destruction, but the key roles that wetlands play in the life cycles of many organisms clearly support the imperative to restore as much land area and diversity in wetland habitats as possible.

II- Management Plan: Goals and Execution

Before delving into issues specific to current and potential constructed wetlands at the PCR, this section will begin by laying out a common framework for wetland restoration and management. We then follow with the identification of specific goals for each site and proposed plans of action for their achievement. The chapter ends with a brief summary and a cursory budget for the restoration plan.

Common Framework for Wetland Restoration/Management

Beyond the specific goals for each site is the overarching necessity of maintaining physical and biotic conditions that will allow these constructed communities to persist. Although substantially different in many physical and biotic respects, a unified conceptual framework for restoration is applicable to both areas, as there are several common aspects of site management that should be addressed for all wetlands.

1. **Comprehensive Physical/Biotic Characterization and Alteration**
   a) Topography
   b) Substrate
   c) Climactic Parameters
   d) Hydrology

2. **Hydrologic Regime Goals**

3. **Biotic Assemblage/Ecosystem Service Goals**

4. **Project Monitoring**

1. Physical/Biotic Characterization
a) Topography

Topographic dimensions of the entire contributing area (local catchment) for each wetland should be surveyed at high resolution. The constructed surface, when associated with groundwater surface and surface water systems will be useful in the process of deciphering hydrologic relationships such as ground water/capillary zone interaction. Depending on construction plans, a detailed topography may be essential for flooding of the pond sites (Bauder, 2005). For such small areas, a Total Station may be the surveying tool of choice, although an RTK (Real Time Kinematic) GPS system may also be useful. Both will provide the level of resolution necessary for characterizing the surface of small landforms such as those found at the PCR.

b) Substrate

In depth characterization of soil and regolith will be informative from both a hydrologic and biotic standpoint. Physical parameters such as saturated hydraulic conductivity will be of particular importance in developing a picture of water loss from subsurface percolation through the mineral soils ponds. Moreover, the chemical constituents of these soils play a large role in determining the plant assemblages that may inhabit these vernal pool type sites, where combinations of hydraulic regimes and nutrient characteristics largely control plant community structure (Wacker and Kelly, 2004). Vernal pool soils are generally sodic, and very compact, thus limiting their viability for many invasive species.

c) Climatic Parameters

Precipitation, solar exposure and wind patterns all play a large role in the moisture regime of most naturally occurring wetlands. Although human controlled introduction of water will be a large component of at least the marsh site, climate remains a sizable factor. The effluent from the aquaculture center may be controlled to maintain desired moisture regimes in the marsh area, but the defunct ponds may be slated for a Mediterranean climate driven moisture regime. Thus, knowledge of the current climate cycles in this area will be crucial to the construction of a hydrologic balance for the pond sites and predictions for future climate changes may help to establish a reasonable range of precipitation availability and evapo-transpiration rates.

Due to the vicinity of the University of California Davis, it may not be necessary to supply instrumentation to the site. The high level of field based agronomic and atmospheric research conducted in the greater Davis area has produced a sizable record of climatic parameters such as precipitation, wind and solar radiation, which may simply be extrapolated from data collection sites nearby.

d) Hydrology

All of the characterizations above lead into the development of a water balance for the marsh and defunct pond sites. This may not seem to be such an important part of managing the freshwater marsh due to direct control of surface water inputs at that site. However, it must be recognized that the water additions are simply a human controlled component of the hydrologic budget for that area. The availability of water from the aquaculture center and their ability to control release timing is therefore of utmost importance for managing the marsh, and depending on development plans, could be the driving factor in constructing wetlands in the ponds as well.

Beyond human inputs, the rest of the hydrologic budget can then be constructed with enough information from characterization steps a) through c), with the exception of groundwater interactions. Due to the proximity of Putah Creek, one suspects that groundwater may be close to the surface at certain points in this area. This component of area hydrology could be studied through the development of several small test wells.

The goals for the upland sites may require the use of various herbicides for the removal of invasive vegetation. Understanding the surface and subsurface hydrologic connectivity of the marsh and defunct pond areas in relation to the spatial distribution of these applications will better inform management of the potential impacts these chemicals may have on the constructed wetlands.

2. Hydrologic Regime Goals

Based on the natural hydrologic regime of these sites and the amount and timing of surface water available from the aquaculture center, as well as the chemical characteristics of this water and the potential groundwater interactions at these sites, hydrologic planning can proceed for all potential wetland areas. One goal for the riparian corridor, which extends from the aquaculture center to the freshwater marshes, is the construction of a holding pond to create the capacity to induce hydrologic pulses through the system (see p.__). Variable inundation of the freshwater marsh site is consistent with natural cycles for marshes in Mediterranean climates. While not essential to the life cycle of the major emergent macrophytes of interest at this site (see below), the potential for routing water into the proximal defunct ponds may be used as a controlled surface water introduction to induce ephemeral perched catchments.

Two general wetland scenarios dependent upon aquaculture water availability and local topography emerge for the defunct ponds:

I. Divert aquiculture effluent to maintain hydrologic regime

II. Use the natural hydrologic regime

Both of these plans may require alteration of substrate physical qualities to ensure perched storage of water on these sites for the residence times necessary for the hydrologic regimes. Choice of hydrologic regime may proceed as one of two choices further detailed in the specific goals section:

A) Extension of freshwater marsh system

B) Establishment of an ephemeral, seasonally saturated system (vernal pools).

A detailed plan for freshwater marsh system expansion is not included in this chapter, in favor of plan B, although the presence of multiple ponds does not make the two mutually exclusive. Ultimately the amount of water available from the aquaculture center will determine the extent of marsh that may be maintained. Vernal pools on the other hand, may persist hydrologically through the manipulation of substrate to capture and hold water throughout the wet season (roughly November through April).

3. Biotic Assemblage/Ecosystem Service Goals

Wetlands are often the site of remarkable biomass production and diversity. Many migratory and resident species of birds and mammals utilize wetlands at some stage in their life cycles and contain many species of insects (some of which can be an issue for human interactions), fish and amphibians. The freshwater marshes at the PCR are already observed to provide habitat for many different species of birds. The largely degraded state of Central Valley wetlands highlights the importance of increasing highly productive areas such as freshwater marshes for the ecosystem services they provide, particularly to migratory species that have fewer habitats to utilize throughout their migratory patterns. Furthermore, freshwater wetlands can sequester carbon, which is of increasing interest in the context of human induced climate change (Zedler and Kercher, 2005).

Although increasing the extent of the freshwater marsh on the site would create more of a precious, highly productive habitat, the argument for experimentation with vernal pool construction may be even more compelling. Vernal pools are vastly degraded throughout California (Rains et al., 2008). Many of the species endemic to these areas are highly specialized, and as such endangered or threatened due to the large scale destruction of these habitats. Therefore, creating vernal pool habitat through hydrologic regime and substrate manipulation could be an interesting and important experiment.

4. Project Monitoring

Ongoing project monitoring is essential for constructed wetlands, all the more so when they rely on external, human controlled water input. Site hydrologic characterization, even with the most sophisticated techniques, often fall far short of accurately predicting hydrologic regimes, thus site observations provide crucial feedback for the ongoing site design/maintenance. The methods detailed above for establishing a hydrologic budget for the site should not be discarded after site construction. The collection of these data should continue, including daily or weekly marsh water level measurements, yearly marsh bathymetry to assess filling by organic matter, as well as measurements of the chemical composition of both water and substrate.

Invasive species often heavily colonize nutrient enriched areas such as fresh water marshes, as can be seen from the large monotypic stands of Yellow Flag Iris (*Iris pseudocorus*) at the PCR. Project monitoring greatly aids in identifying such incursions and eradicating them. Observers should become proficient in identifying this plant at all stages of its life cycle, and open areas of the marsh banks due to die-backs or disturbances should be particularly well observed.

Specific Restoration Goals and Plan of Action

The Putah Creek Reserve (PCR) site contains two distinct groups of landforms that may be managed as artificial wetlands.

- Freshwater marsh
- Defunct ponds

Both areas are already highly modified systems; the former must be managed as a wetland with at least one specific service issue (effluent treatment), while the latter may be seen as an experimental zone more open to creative control. The actual mitigation of the defunct ponds may be restored as per other upland habitats in the PCR, however this chapter will proceed with recommendations assuming that they are chosen for treatment as wetlands.

Freshwater Marsh

Goals

Large monotypic stands of the invasive Yellow Flag Iris currently dominate the freshwater marsh borders zones where topography in relation to the fluctuating water surface allows for the growth of emergent macrophytes. Moreover, the slope of this border area is relatively steep, which has created an abrupt transition between littoral zones of floating/emergent vegetation to high marsh and upland zones. The major goals for restoration at this site are the following:

1. Completely remove Yellow Flag Iris (*Iris pseudacorus*)
2. Re-grade the marsh edges to produce a larger transitional zone between saturated and unsaturated substrate conditions.
3. Re-vegetate the marsh edges with emergent and high marsh species native to the Great Central Valley of California.
4. Maintain treatment of aquiculture effluent.

Execution

1. Techniques for the removal of Yellow Flag Iris are detailed in the chapter dedicated to this species (p.__), but include mechanical, manual and chemical means. Due to hydraulic connectivity with Putah Creek particular care must be taken with herbicide use for this wetland.

2. Re-grading the marsh edges should follow a plan based on the local topography (see below). The proximity of the dirt road to some wetland banks may preclude bank alteration in those areas as creating a lower bank slope is contingent upon pushing the bank crest back from the marsh rather than filling the marsh in. The marsh has already been observed to be rather shallow and will become shallower with the deposition of organic material over time.

Heavy equipment will certainly be necessary for a land surface alteration of this scale, but this does not seem to be a limiting factor, as the PCR staff have such machinery at their disposal and are skilled in their operation. This should also lower the projected costs of the project (see Preliminary Budget, this chapter).

Creating a larger emergent to high marsh zone will increase the evapo-transpiration of the marshes. This may need to be taken into consideration when planning the water budget for this site, as substantial increases in marsh surface area and vegetation, along with potentially adding other marshes through defunct pond alteration may outstrip the capacity of aquaculture center effluent flux.

3. Likely candidates for re-vegetation of the marsh edges include emergent macrophytes such as *Typha* latifolia (Cat Tail), *Schoenoplectus californicus* (California Bullrush), *Schoenoplectus americanus* (Olney's Bulrush) and *Juncus* (rushes), along with high marsh *Carex* (sedges). A mixture of Typha and Schoenoplectus may be beneficial if nutrient gradients are present, as Typha will generally out-perform Schoenoplectus in higher nutrient situations, while Schoenoplectus may establish dominantly in somewhat lower nutrient areas (in the context of a generally nutrient rich system)(Svengsouk and Mitsch, 2001). All species should be broadcast as seeds or introduced through plugs, seedlings, or rhizome transplants, as mass removal of Yellow Flag Iris and re-grading of the site precludes the possibility of fostering current populations of these plants, if indeed any are present beyond a few small stands of *Typha*.

If seeds are to be used, the particular requirement of each species must be taken into consideration. The seeds of Carex species are known to degrade relatively quickly, and should be from a fresh source, preferably less than 6 months old (van der Valk et al., 1999). Typha and Schoenoplectus are generally introduced through rhizome cuttings, which could be obtained from communities in nearby wetlands or perhaps local researchers at UC Davis (further reducing costs). Acquiring cuttings from several locations will help to increase the genetic diversity of the stands.

4. Aquiculture effluent treatment will be maintained as long as the connection to Putah Creek is no altered. This must be factored into any plans to re-grade the site, but should not be a large concern unless plans for landscape alteration extent to that particular part of the marsh.

Defunct Ponds

<u>Goals</u>

The approach to constructing wetlands in these areas could potentially follow two different paths, *i*) an extension of the freshwater marsh system through direct hydrologic connectivity, or *ii*) creating vernal pool habitats. As freshwater marsh issues will be detailed for the sites currently under this designation, this chapter will mostly focus on the development of vernal pools from the defunct ponds.

The main goals relevant to constructing vernal pools at these sites are:

1. Remove current upland plant species.
2. Develop a moisture regime analogous to vernal pools in this region.
3. Establish and sustain communities of vernal pool flora and fauna.

<u>Execution</u>

1. Strategies for the removal of upland invasive species, and perhaps even natives in this case, are amply addressed in other sections of this manual. One consideration specific to sites slated for vernal pool construction is the effect of the current root structures on the hydraulic conductivity of the soil. Excavation may be a necessary precursor to the reworking of soil characteristics to match the desired water holding capacity of the substrate.

2. Central Valley vernal pools are associated with low gradient areas of minor depression underlain by clay-rich alluvium and are generally nitrogen limited (Rains et al., 2008). Modification of the hydrologic conductivity of the soil to create a seasonally perched surface water system is generally accomplished by the addition of soda ash or swelling clays such as Bentonite to achieve infiltration rates on the order of 10E-6 to 10E-7 cm/s (Chipping, 2000). The substrate of vernal pools also possesses complex micro-biota which are poorly understood. Thus, while short term success in terms of hydraulic characteristics may be relatively easily achievable, the probability of long term success may be enhanced by the indroduction of actual soil from regional vernal pools that are destroyed elsewhere for development purposes. Although inoculation may cause problems regarding genetic diversity in micro-fauna, the introduction of such material may achieve many substrate characteristics crucial to vegetation establishment, yet currently unknown to the restoration ecologist (Chipping, 2000).

3. Vernal pool vegetation and faunal communities will have to be introduced to the site, as none are known to currently inhabit the area. Unfortunately, propagation characteristics of the edaphic plants present in vernal pools is generally poorly understood and seeds/propagules are typically difficult to obtain. Much more research on the propagation of species and construction of plant assemblages in constructed vernal pools is required (Wacker and Kelly, 2004).

However, this may be seen as an opportunity for valuable research on vernal pool construction and management at this site, rather than a hindrance to site restoration success. The current layout of multiple defunct pond sites presents a setting for multiple treatments, in terms of substrate alteration, vegetation/faunal introduction methods and assemblages, and even surface water introductions for those sites most proximal to the freshwater marshes.

Summary

The freshwater marsh is an artificial wetland currently used to mediate the water quality of aquiculture effluent en route to Putah Creek. The functionality of this wetland as a water treatment installation should be maintained. Regrading the marsh boundaries constitutes an expansion of marsh extent and hydrologic budget, further underscoring the need for accurate hydrologic and topographic data for the site. Infringement on roads through this expansion may be a limiting factor, as this is a multi-use area.

The drained pond systems appear to have been upland areas that were dug and lined with substrate of lower hydraulic conductivity in the mid 20^{th} century to hold water for research purposes. No externally derived, area specific constraints beyond those that apply to the entire PCR site are of concern for the drained ponds, although there are certain physical/biotic issues that must be taken into account. Efforts to establish seasonal, vernal pool type habitats or extend fresh water marsh cover into the defunct ponds will require a firm understanding of the hydrologic balance for those areas and also relies upon a thorough understanding of the water resources available from the aquaculture center. Finally, attempts to establish vernal pools will require substantial amount of research, much of which may be performed as trial and error at this site.

III – Restoration Goals in the Context of the PCR Project

The goals for the upland sites at the PCR generally have little bearing on wetland activities proposed above. Some defunct pond areas will most likely be treated as upland habitat, but this does not hamper the restoration plans for the remaining sites. Much concern is allocated to charismatic macrofauna, such as the Giant Garter Snake (*Thamnophis gigas*), but the high ground requirements for this species in the advent of flooding is nothing more than an additional consideration that can easily be built into the planned topography for the marsh edge zone. The greatest concern with upland site manipulations in the context of wetland restoration is the application of herbicides. Local topography and hydrology must be accounted for along with climate when deciding the amount, timing and spatial distribution of application (during the dry season, and generally far away from the wetlands. Herbicide runoff into the wetland area is preferable to it first entering Putah Creek, however the hydrologic connectivity between the two bodies also suggests that polluting the marshes should be avoided if at all possible.

Of more relevance is the planned alteration of the channel connecting the aquaculture center to the marshes. This construction effort may contribute significant amounts of sediment to the marsh, altering the flow characteristics. Great care should be taken to control sediment movement into the marshes to avoid further silting them in. Furthermore, diversion of effluent waters during the construction process may lead to periods of rapid water surface elevation change. Although the vegetation present in the marsh will not necessarily be adversely effected by periodic changes in water level, the complete desiccation of the marshes would most likely decimate a significant amount of aquatic life (fish, some amphibians depending on timing).

Finally, plans for the riparian corridor include developing capacity for high flow pulses. This is a common component of natural freshwater marsh hydrologic regimes, particularly in climates that possess a dry season. Thus, the planned flood pulses should not be a problem for the marsh community. Of course, these releases of water should be carefully considered in relation to the capacity of the marshes and the desired level of flooding in the general area.

Preliminary Budget

	Item	Units	Unit Cost	Subtotal
Restoration	Heavy Equipment Operation			
	*Labor	100 hrs	$0/hr	$0
	Fuel, maintenance, etc.	100 hrs	$50/hr	$5,000
	Manual removal of Yellow Flag Iris			
	Misc. Tools & Equipment			$200
	* Labor	200 hrs	$0/hr	$0
	Planting Labor	200 hrs	$0/hr	$0
	Carex Seed (for 1 acre)	15 lbs	$5/oz.	$1,200
	Typha and Schoenoplectus Rhizomes			
	Transport and material costs			$500
	*Labor	100 hrs	$0/hr	$0
	Soil Adjustment (Bentonite, etc.)			$1,000
Site Characterization	‡Monitor Wells	10	$500	$5,000
	Instrumentation (TDR, pH meters, infiltrometers, etc.)			$2,000
	Collation of off-site data	50 hrs	$0/hr	$0
	†High Resolution Survey			$5,000
	*General Field Work	100 hrs	$0/hr	$0
Total				$19,900

*** Labor costs assumed implicit in staff salaries, with additional work done by volunteers**
‡ Well costs on the low end of the spectrum ($500 to $1,500/well).
† Survey costs could be greatly reduced by utilizing UC Davis researchers/students.

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Native Plants

Native woody species

Corey Hamza
ENH 160
Project Final
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Valley Oak

A. Since the arrival of European settlers to California, 90% of Valley Oak woodlands in the Central Valley have been cleared to make room for agriculture and urban development. Currently, there are two main threats to Valley Oak woodlands: mature tree removal, and a significant lack in seedling and sapling recruitment. (Crawford, 1998) The goal of this project is primarily to establish and outline what is needed to restore Valley Oak woodlands; and secondarily to outline a viable course of action to conserve remaining Valley Oak woodlands. To accomplish this comprehensive goal will require the combined efforts of many different individuals and institutions with a wide array of expertise and influential abilities. The conservation portion of the project will require state policy makers; government organizations (i.e. The Bureau of Land Mangagement (BLM), etc.); NGOs such as the Integrated Hardwood Range Management Program (IHRMP); as well as private landowners, considering that 80% of California's Hardwood Rangelands are privately owned. The restoration portion will require the expertise of organizations like the IHRMP and UC Extension researchers who will be engaged primarily in education and project procedure, as well as the implementation and management of agencies like BLM and who oversee and manage efforts, and of course private landowners.

The need for Valley Oak Conservation and Restoration is multifold. Valley Oak woodlands serve many purposes including wildlife habitat and food resources; ecosystem functions such as nutrient cycling, water flow, and micro/ regional climate regulation; cultural and aesthetic values, as well as many economic values. Over 300 vertebrate species utilize oak woodlands including birds, reptiles, amphibians, and mammals. Valley Oaks have tap roots that penetrate as deep as they are tall, and in many cases, even deeper. Consequently, they scavenge nutrients that are well below the root zones of most other species, especially annuals, and deposit them on the soil surface when they lose their leaves. Their roots also act as sponges, slowing infiltration and maintaining high moisture levels in the soil around them, and their canopy cover reduces local soil temperatures and evaporation of that water. By altering the composition, or in many cases, the existence of Valley Oak woodlands, many of these species are significantly affected. From a broader environmental scale, oak woodlands slow wind speeds, provide habitat corridors, reduce soil temperatures, and slow the travel of water through watersheds so that fisheries and humans alike have a steady supply of water throughout the year. From a cultural and aesthetic standpoint, Valley Oaks historically played an important role as a Native

Californian food source, some of whom received over 50% of their diet from the bountiful production of acorns. In post colonial times, Valley Oaks have served as valuable sources of fuel-wood; habitat for hunting, hiking, and the like; and are in general a symbol of California along with the many other oak species. In economic terms, Valley Oak woodlands provide productive rangelands for domestic grazing, with less heat stress due to the shade provided by the trees; as well as the fact that properties with a certain number of oaks are up to 20% more valuable real estate than similar properties without the trees. (Giusti & Tinnin, 1993)

Fortunately, the need for conservation and restoration has not gone unanswered. The organization who has spearheaded all oak woodland conservation and restoration in California is The Integrated Hardwood Range Management Program, formed in 1986 with the mission "to maintain, and where possible, increase acreage of California's hardwood range resources to provide wildlife habitat, recreational opportunities, wood and livestock products, high quality water supply, and aesthetic value." The objectives of the program are as follows.

-Develop methods to sustain hardwood rangeland ecosystems and landscapes;

-Maintain wildlife habitat on hardwood rangelands;

-Restore degraded hardwood rangelands;

-Ensure land use planning utilizing available information to conserve hardwood rangeland ecosystems;

-Maintain economically viable private hardwood rangeland enterprises;

-Maintain statewide information base about trend, condition, and extent of hardwood rangelands; and

-Help focus public awareness about the importance of hardwood rangeland habitats (Univ. of Calif. Integrated Harwood Range Management Program)

To a large extent, their projects and objectives are congruent with the goals of this project.

In addition, 2001 saw the signing into legislation of the California Oak Woodland Conservation Act. The act was created with the specific intent of accomplishing the following goals.

-"Support and encourage voluntary, long-term private stewardship and conservation of California oak woodlands by offering landowners financial incentives to protect and promote biologically functional oak woodlands;

- Provide incentives to protect and encourage farming and ranching operations that are operated in a manner that protect and promote healthy oak woodlands;

-Provide incentives for the protection of oak trees, providing superior wildlife values on private land, and;

- Encourage planning that is consistent with oak woodland preservation." (McCreary D. , 2004)

The primary advantage or benefit that the Act provides over the work of IHRMP, aside from its legal power is its potential to provide conservation and restoration efforts with needed monetary funds. "As a result of the Act, the Oak Woodland Conservation Program was established. This Program, administered by the Wildlife Conservation Board (WCB), is designed to provide $10 million to help local jurisdictions protect and enhance their oak woodland resources. It offers landowners, conservation organizations, and cities and counties an opportunity to obtain funding for projects designed to conserve and restore California's oak woodlands. It authorizes the WCB to purchase oak woodland conservation easements and provide grants for land improvements and oak restoration efforts. While the Program is statewide in nature, it is designed to address oak woodland issues on a regional priority basis. Most importantly, this Program provides a mechanism to bring ranchers and conservationists together in a manner that simultaneously allows both to achieve that which is so valued -- sustainable ranch and farming operations, along with healthy oak woodlands." (McCreary D. , 2004)

B. The Valley Oak, botanically known as Quercus Lobata, is "reputedly the largest North American oak," with trunk diameters reaching 2 meters. The valley oak occupies three distinct bio-geographic locations. These are, "riparian areas and floodplains, alluvial fans and occasional flat areas, and upland terraces and plateaus." Valley oaks typically grow at elevations below 2,000 feet, with occasional establishment up to 5,600 feet. They prefer fertile deep soils where water is available. In riparian zones, where water is readily available, Valley Oaks form dense forest stands with an erect structure and are characterized by rapid growth. In drier oak savannahs, they grow slower, spread further apart, and are characterized by their arching branches that can reach the ground. Their range is limited to California, but spans the entire Central Valley as well as the Coastal Ranges from Mendocino County to the Central Coast ranges. (Giusti & Tinnin, 1993) This habitat description of the Valley Oak could very easily be mistaken for where a farmer would want to clear land to grow crops, or where a developer would begin their urban and suburban sprawl; flat deep fertile soil with plenty of water and near rivers. It is therefore no wonder that over 90% of Valley Oak woodlands have been cleared. If it were not for the Coast Ranges existence, that figure could very well be closer to 100%.

Given the Valley Oak's current situation, conservation of remaining woodlands is imperative; however, significant restoration efforts are equally needed to spread these woodlands and all the biota that depend on them for survival. While the implications of this undertaking vary on the specific site, a general model for successful Valley Oak restoration can be established.

The vast majority of restoration sites are going to be in agriculture dominated regions. Over the past 150 years, as the rivers and streams of the Central Valley have been channelized and the surrounding land converted to agriculture, the riparian forests that accompany these water systems has decreased by up to 89%. These riparian zones are critical habitat for many endemic species to California. As they have been destroyed, many of these species, including the Elderberry Longhorn Beetle have become endangered. (Valley Elderberry Longhorn Beetle) It is these riparian zones that are the best candidate for Valley Oak woodland restoration. By doubling or tripling the width of these forests along rivers and streams, vast areas of contiguous habitat can be restored to Valley oak woodland. Ideally, historical evidence of the original size of the riparian zones would serve as a guide to the size of the restoration project; however this ideal may be unrealistic due to the scope of the area or ability to acquire needed land. The area that would be converted currently exists as agricultural land. The first step in restoration would be the procurement of these lands from current landowners, either through costly purchase; or perhaps negotiated as easements for some benefit to the landowner. Local government will have to approve the project, and the zoning of the area will most likely have to be changed. A common problem in convincing the county, is that the restoration site, once taken out of private ownership is a loss of tax income to them, and so convincing local/ regional government may become a serious hurdle. Once acquired, the community must be included if the project is to succeed. The community may be very accepting of the project or not; but either way, public education and involvement is a critical issue to the success of the project. Local schools and the community as a whole can become involved in the actual implementation of the project, which could potentially be a significant savings in labor cost. Other social issues that must be dealt with include flood control issues, especially if channel levees are to be removed and set back levees put in place. Many farmers view riparian and marginal land areas as weed seed factories and so their fears must be dealt with and put to rest. There are many other potential issues as well, but once all of the social issues are taken care of, the site must be analyzed and a budget constructed and funds secured. This includes analyzing the physical state of the land. The soil should be analyzed for composition, texture, structure, and depth. (Giusti & Tinnin, 1993) In all likelihood, there is going to be a problem with weeds, and so choosing whether to incorporate the use of mulches or herbicides must be determined. A variety of geo-physical ailments at the site may exist as well. It is possible that due to agriculture, the site has become depleted of key nutrients which are critical to the establishment of the Valley Oaks, or perhaps there are too high levels of nutrients. In this case, proper soil amendments must be added or successional species grown to make the soil favorable. In addition, the water table may have been depressed due to groundwater pumping, and therefore permanently made unsuitable for oak establishment. This is more likely to be a problem in flood plain areas and uplands rather than riparian areas, but is nevertheless a potentially serious problem that is irreversible. Once all of the geophysical problems are established, a course of action must be prepared to address the issue. In the case of riparian areas, set back levees may need to be constructed if existing levees are to be removed. This is a huge undertaking, requiring the use of heavy machinery and adding a significant cost to the project.

Once geophysical alterations are taken care of and budgeted, the biological component must be analyzed; a plan developed for carrying out the project, and budgeted. There are a number of studies and trials on Valley Oak restoration that have been conducted by UC Cooperative Extension and the IHRMP, as well as by many others; and a synthesis of the results for the best strategy will be presented.

As previously stated, Valley Oaks are undergoing severely depressed rates of seedling and sapling recruitment for a variety of reasons. Valley Oaks often produce prodigious numbers of acorns from which new seedlings sprout, and therefore the problem is not in reproduction. Once acorns fall from the tree and sometimes before, they undergo a barrage of unfavorable conditions and predation. The acorns are viable as soon as they form and fall from the tree. Once they fall, they are very limited in their ability to disperse, mainly being transported by organisms wanting to feed on them. Many acorns fall victim to consumption by insects and microorganisms, primarily filbertworms (*Cydia latiferreana*) and filbert weevils (*Curculio spp.*). In addition, the vast majority of acorns are consumed by vertebrates. These include over 30 species of birds, and 37 species of terrestrial mammals, principally voles, gophers, ground squirrels, rabbits, deer, and feral pigs, depending on the location. (Swiecki & Bernhardt, 1991) In addition, acorns are subject to losing their viability in hot weather as they lose moisture. Once the acorns manage to sprout, which is preceded by extensive root formation, often up to a foot, before there is any aboveground emergence; they are subject to a heavy dose of herbivory, often by the aforementioned vertebrate mammals. New seedlings also experience heavy competition from herbaceous plants, namely grasses, for space and water. These are the environmental conditions and constraints which the restoration team must deal with in their management strategies.

In 1985, Theodore E. Adams, Jr. of UC Davis examined various techniques to enhance Valley Oak and closely related Blue Oak regeneration at the UC Hopland Research and Extension Center in Mendocino County over 5 seasons. He found that the most important factor to reducing moisture stress in young seedlings was weed control, where weeded sites experienced a 60% emergence rate in comparison to 46% for non-weeded sites and first year survival was likewise 45% and 29% between the two treatments. He also found that 80% of all mortality in seedlings was caused by rodents, and aggravated by weeding around the seedling. In some cases, gophers destroyed 95% of unprotected seedlings. However, over the 5 growing seasons, he achieved a 60% survival rate when weeds were controlled and screens were placed over the seedlings to protect them from herbivory. (Theodore E. Adams, 1994) In a similar study done on Vole predation, by Jerry Tecklin, it was concluded that a 4 foot diameter weeding around the seedling, along with 4 foot tree shelters sunk a few inches below the ground, provided the best survival and growth results. It is apparent that weed control in a 4 foot diameter around the seedling and seedling protection to around 4 feet is what has worked the best. (McCreary & Tecklin, Effects of Tree Shelters and Weed Control on Blue Oak Growth and Survival, 1992) In addition, nearly all experiments regularly watered the seedlings during the first two years of growth, and found best survival rates with nursery stock over direct seeded acorns. Interestingly, in a 1989-1991 study of top pruning on Blue oak seedlings resulted in interesting results. In container grown blue oak seedlings, that were transplanted, taller seedlings that were top pruned up to 60% of their height. By the second growing season after pruning, the pruned seedling had substantially more height growth than either of the controls, as well as greater increase in girth. (McCreary & Tecklin, 1992) While not Valley Oaks, the results of these related blue oaks are intriguing. In future trial studies, shorter versus taller tree shelters should be compared for long term seedling growth. As a result of all these studies an ideal application can be derived. It will be suggested here that nursery stock seedlings be transplanted in a hole 1.5 feet deep and 1 foot wide. A four foot diameter area around the seedling will be cleared of all vegetation and a durable organic cloth such as hemp will be placed over the area to mitigate and prevent herbaceous plants from growing in the area. The organic cloth will slowly degrade over time once the tree is established, and therefore not persist in the environment such as plastic or need to be removed; and will also provide a more effective barrier than wood chips or similar mulches. A tree shelter of 3-4 feet in height will be placed over the seedling and submerged several inches into the ground to prevent gopher predation. Current tree shelters are made by Tubex and work well, (Kraetsch, 2002) although biodegradable plastic tree shelters made of PHA plastic should be potentially used in the future should they become available, as they will not need to ever be removed from the site because they will slowly degrade. Irrigation during the growing season should be applied for at least the first two growing seasons after transplant and potentially longer if needed.

There are very few long term studies to draw data from, however, current evidence and research suggests that the above guide to Valley Oak seedling establishment will result in the highest establishment and overall success rate.

The Restoration and Conservation of Valley Oak Woodlands in California is imperative to maintaining the state’s level of biodiversity as well as the function of its Central Valley ecosystems. This project is an overview of the steps required to carrying out a successful restoration of Valley Oaks. Like a metaphorical tree of life, the Valley Oak provides life to many animals and plants in California, including us, it would a crying shame to lose it, knowing we could have made a difference.

Part II

The primary goal of the restoration project is to establish, in time, a mature Valley Oak dominated woodland in the riparian to upland area along a given river, creek, or stream. In order to achieve this goal, several subsequent goals must be achieved. First, a site must be acquired either through financial means or as a collaborative effort with government or private land owners. Second, a restoration plan must be designed and established for the site. There are a wide variety of riparian and upland native grasses and forbs, as well as other tree species that live in coexistence with oaks. Which species are to be restored along with the oaks must be selected as well as how to manage and monitor all of the species, without negatively affecting any of the others. These can include woody species such as cottonwood, alder, black walnut, willow, and others; as well as understory species such as elderberry, coyote bush, poison oak, blackberry and a variety of annual and perennial grasses and forbs. The next goal is to collect seed stock from as close to the site region as possible, in order to maintain unique genetic ecotypes, which may possess locally adapted traits; and subsequently start them in a nursery type setting. Once the seedlings are ready, they will need to be transplanted to the site and irrigation and seedling protection aids must be constructed and put in place. The final goal is to successfully monitor and manage the oak trees where necessary until they have reached a self-sufficient size. In the end, the oaks will hopefully be one part of a diverse functional ecosystem.

The temporal scale of this goal has two parts. For the restored trees to become self-sustaining will require a monitoring and management period of 3 years at minimum and 5-10 years at maximum for a given site; but the trees will not become mature until the age of 20-30, which is when potential seed recruitment may occur. As a result, a second stage of monitoring may be advantageous at this time, to study whether successful seedling recruitment is occurring.

The spatial scale of the project can vary greatly in size, depending on site constraints and other logistical issues. (e.g. finances, existing permanent structures, etc.)

At a given site, the woodland corridor should extend width wise as far as possible, in order to properly function as a wildlife corridor. At certain sites this may be impossible and at others it may be able to be exceeded. The other restoration goals for a given site must also be taken into account. For example, at our site, grass/ forb prairies are trying to be established, so oak planting densities and location must be planned to not compromise other site goals. Valley Oaks typically grow in a savannah like manner in uplands, and so sparsely planted trees in these areas further from the river or stream can facilitate the establishment of other desirable species. The planting density and overall layout can have many effects on wildlife as well, so different arrangements can be used to help support the needs of different wildlife species.

Ideally, the woodland would be established within a setback levee to protect against 50-100 year floods, and help foster public and government support. The spatial considerations of the restoration should also take into account the habitat needs of endangered and threatened riparian wildlife, to ensure that the size parameters can meet most or all of their habitat needs as well (e.g. Elderberry and Elderberry Longhorn beetle) On many sites, current channel levels will have to be removed and set back levees will have to be constructed. The economic and labor scale of such activities is enormous. In such cases, there is really no alternative to having strong state and even federal funding for the project. Interestingly, the potential flood control and safety provided by setback levees, and considering the risks and dangers associated with the current state of many of our levees, a federal and state backing may not be out of sight, if the project is presented correctly.

Several other constraints will limit the feasibility of these goals as well. First of all, the funds required to purchase valuable farmland that now borders all of these riparian sites will be an extraordinary sum, and will very likely limit the size of many projects. Similarly, current landowners will have to be willing to sell. In addition, Public support is imperative, as is long term monitoring of the site, and therefore local state or NGO agencies must be collaborated with (i.e. Parks Department, BLM, etc.) The oaks and any other species will also have to be established to a self sustaining state within a short window of time due to funding constraints, unless monitoring is passed on to another management group.

Many ecological constraints to the restoration exist as well. The young oaks are highly prone to desiccation in their first couple years and supplemental irrigation in the summer is therefore imperative. Mature trees can have tap roots that grow 70 feet deep, but regardless, valley oaks must have access to the water table. In many areas, the water table has been lowered due to pumping for agriculture and has resulted in die-offs of mature Valley Oaks. (Howard, 1992) The biggest biological threats to the restoration are as follows. Vigorous annuals whether exotic or native, can easily out-compete young seedlings for light, water, and nutrients. In addition, young seedlings are very vulnerable to predation by opportunistic herbivores, including deer, rabbits, ground squirrels, voles, gophers, among others. To mitigate for these threats, proper management techniques must be employed, which will be discussed.

Furthermore, the site is not just for oaks, and therefore the needs of other native species that are trying to be reestablished must be taken into account. In the re-establishment of native grass species, fire is a useful tool to manage for weed species, but this would not be possible if oaks were being restored on the site, at least until the oaks were of a height and size able to withstand the fire. In addition, if grazing is to be used in the restoration area, the oak seedlings will need to be protected with a cage in addition to a tree shelter, but this is a constraint that can be effectively dealt with. For each site, there will be different obstacles and issues to deal with, depending on the location and its inherent constraints as well as the size.

Spatial scale of Valley Oak restoration can be highly variable. In woodlands closer to riparian zones, planting density will be denser and gradually become less dense as you move into more upland areas.

Due to the spatial scale in some instances, and in the interest of time and financial efficiency, the restoration will have to be highly intensive in the beginning. Valley Oak trees will first be raised as nursery stock for transplant. The ecotype seed source will ideally be from remnant Valley Oaks in the region and will be raised as close to the site as possible, to reduce transportation costs. Direct seeding is not an option because it is too un-reliable in terms of survivorship, and is highly unmanageable, requiring longer more intense, inefficient management. Consequently, the cost would be significantly higher and the temporal scale of management severally extended.

Prior to planting, drip tape will be installed 1 foot or more below the soil using tractors and laid out in a more or less orchard type matrix, due to ease of management. Then, ideally volunteers will provide the labor for planting the seedlings. First, a four foot diameter area around the seedling will be cleared of all vegetation and a durable organic cloth such as hemp will be placed over the area to mitigate and prevent herbaceous plants from growing in the area. The organic cloth will slowly degrade over time once the tree is established, and therefore not persist in the environment such as plastic or need to be removed; and will also provide a more effective barrier than wood chips or similar mulches. After the seedlings are planted, 3-4 foot tree shelters will be placed over the seedlings to protect them from herbivory, and submerged several inches below the soil to prevent gopher predation. Ideally they will be constructed of biodegradable PHA plastic that is durable in the short term, to prevent from having to remove them all later; although if cost favors conventional tree shelters than that is the best choice. The sheet mulching will prevent from having to continually spray herbicides to kill competing annual weeds, reducing labor and cost. Should cost permit, using agricultural waste products such as walnut shells could be a cost efficient alternative. The irrigation will be provided via a semi permanent solar powered pumping system that will pump water from the given stream or river, should access be granted. Should it not, the entire project could be in jeopardy. The irrigation will occur every two weeks in the summer for the first 2-3 years, at which point the drip tape can be removed if possible as well as the solar pump. (Howard, 1992) In many ways the management is set up to be as extensive as possible to reduce costs, however many of the methods are still intensive. A biodegradable plastic drip tape that will last 2-3 years would be a great alternative, because you will not have to worry about leaving miles of plastic at your site in perpetuity, or trying to remove it. Although, I highly doubt this would ever be manufactured, as it has no other application. This system is set up to be able to restore a lot of land with a minimum amount of management. The trees will still have to be regularly monitored, but labor will be kept to a minimum. Other tree species of interest can also be concurrently planted with the oaks and irrigated as well, if needed.

The main monitoring activity will be to see how well the seedlings are surviving and if not, to determine what the problem is. During the first six months, the seedlings and drip tape should be monitored every two weeks, when they are watered, to check for survivorship and any potential issues with the irrigation and barriers. The goal is to have a 70%- 80% survivorship of planted seedlings to reach sapling age. This survivorship level has been accomplished at several restoration sites including Audubon California's Bobcat Ranch, and at the Consumnes River Preserve of Sacramento County, where 95% seedling survival was accomplished in the first three years, although the project will still be a success at lower survivorship levels as well. In upland areas, survival of fewer individuals is more likely and acceptable. (Howard, 1992)

In this system, maintenance of the drip tape will probably be the biggest monitoring/ maintenance activity. Drip tape is highly prone to clogging, being chewed through by gophers and the like, among a whole array of other issues. If the drip tape appears to be a real management upkeep problem, future sites could have the drip tape hung from tree shelter to tree shelter with single emitters at each tree, or some other experimental way of laying the drip line to prevent damage.

Risks include the mulching not being an effective weed prevention tool; the drip tape failing; the tree roots being eaten by gophers and/ or fed upon in some other way; and near surface accumulation of the trees roots due to the near surface irrigation, which would prevent the needed deep tap root penetration to the water table. Of these, drip tape failure and improper root growth are the biggest risks to the long term viability of the project. The other risks, while still a setback, can be successfully dealt with. Alternative mulches can be experimented with as well as other predation control measures, and implemented after the initial planting.

There are several research questions that need to be answered. As mentioned, will near surface irrigation cause the Valley Oaks' roots to grow improperly? In addition, the effects of fertilizer on Valley Oak seedlings should be studied, because it could potentially be a useful tool in decreasing the time to establishment and overall vigor of the trees. Cursory studies have shown that in some cases significant amounts of herbivory in young seedlings actually accelerates growth in the following growing season, which again would provide similar potential benefits to that of fertilizer application, and therefore should be studied. Finally, the mycorrhizal associations of Valley Oaks are not really understood very well and should be studied. Acorns and/ or seedlings could be inoculated with particular fungi to promote more successful establishment, should a positive interaction exist. Due to the scale and continual ongoing progression of the restoration project, any of these studies could easily use the restoration sites as grounds for experimentation and trial. In fact, grant money for research could go directly towards restoration if the sites are used as test plots.

Part III

California Valley Oaks are very unique, in that they can coexist with a wide variety of other species and they provide habitat for an extraordinary number of animals as well. Consequently, there are very few conflicts with other goals for the site, and instead there are consistently win-win situations.

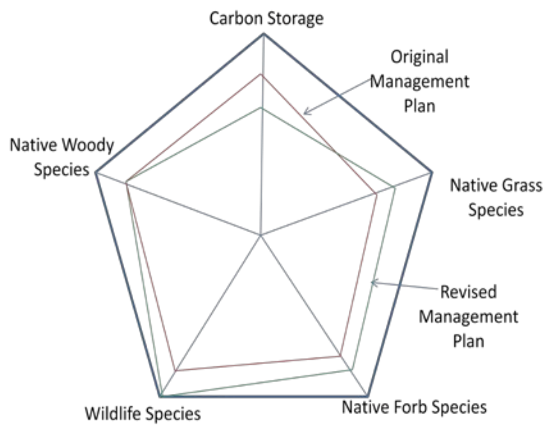
Of the woody species that the class studied, Valley Oaks are commonly associated with all of them, either in riparian forests or upland oak woodland-savannah. Likewise, Valley Oaks can coexist with many if not all of the forb and grass species of interest, especially in an upland savannah setting. When mature, Valley Oaks will shade out some species under their canopy, but also create microclimates for others. Valley Oaks will benefit, as will all of the desired species, from weed control, however they may be vulnerable to certain classes of herbicides. As far as wildlife habitat is concerned, Valley Oaks provide habitat that support over 300 vertebrate species (Giusti & Tinnin, 1993), including 67 nesting bird species in Valley Oak riparian forests, and all of our studied species. This is more than any other California habitat for which such research has been conducted. (Howard, 1992)

In addition, Valley Oaks will be a key contributor to onsite carbon storage, being the largest of all North American Oaks; having a fast growth rate, capable of reaching 20 feet in the first 5 years; and being long lived 250-300 years. Valley Oaks are also adapted to fire, even as a seedlings; where shoots will re-sprout from the crown, should they be burned. (Howard, 1992) Consequently, Valley Oaks will not be harmed and may even be aided by prescribed burns. If fuel loads build up on the ground, a fire could burn hot enough and long enough to kill a mature oak tree. Therefore, frequent burns will minimize this risk. They will need to be protected from grazing however, until they are above the browsing line, and so this is a management problem that can be readily dealt with in a successful manner, without negatively affecting other species.

Of the four principle habitats at our site, Valley Oaks can exist and should be planted in all except freshwater wetlands. In fact, the simulated flooding that is potentially planned is imperative to the successful natural recruitment of Valley Oak seedlings, once they become sexually mature and bear acorns.

There is very little to modify from my original plan, but there are some key issues. When sparsely planted, drip irrigation will be more cumbersome, but still potentially possible. The other issue with drip irrigation is that if it is not buried, it would not work synonymously with grazing, mowing, or fire regimes. The use of tractors at the site may not be feasible either, or perhaps if they are, laying drip tape should be the first order of business after weed control, before any planting, to avoid injuring other species. So, if I were to make a major management change, it would be to not use tractors to lay drip line where their use is impractical. For example, tractors would not be appropriate where the ground is to steep, where there presently exist trees and other woody species, and perhaps not where oaks are very widely spaced. Tractors also pose the problem of soil compaction. Following, the other big management change would be to include cages around the trees in areas where grazing is to be instituted. This adds cost and labor, but does not negatively affect other species.

In addition, the scale will not be as big as originally planned. Principally because the planting density will be much lower in the upland areas as compared to the riparian forest areas and not a continuous orchard like matrix. While this creates more management constraints for the oaks, it allows many more species to exist in greater populations, and accounts for the structure of the upland habitat areas. Below is a trade-off diagram between my original and final management plan.



Under the original plan, Valley oaks were to be inter-planted with other woody species and so the new plan will not have an effect on the densities and presence of other woody species. Under the original plan, planting density of Valley Oaks was going to be denser and so carbon storage benefits were greater under the original plan, due to the presence of more oaks. Under the new management plan, both grasses and forbs are positively affected, because the canopy cover is less dense in the upland savannah areas and so there is more available sunlight for both of these species groups. Finally, it is my belief that wildlife diversity levels will be positively affected by a more varied oak canopy cover allowing for more microclimates and habitat functions. For example, in the upland grass- forb-oak savannah, there will be areas for the Western Pond turtle and other reptiles to sun bathe and incubate their eggs, where there wouldn't have been in a continuous oak woodland.

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Patrick Bushe
4/23/09
ENH 160

Willow (*Salix Sp.*)

Native to most of California, the Willow (*Salix sp.*) plays a huge role in the states natural environments. Due to the degradation of California's open spaces the willow population is gradually declining, much of which is due to urban expansion. The Willow provides us with several benefits that make it an irreplaceable species. “*Salix* is a colonizing floodplain genus characterized by vigorous growth rate and production of a massive root system that can rapidly stabilize stream bank sediments (Grissinger and Bowie, 1984). It also occurs in ditches and on the edges of swamps, lakeshores and other wetland habitats. It is ideal for stream bank restoration because of its easily propagation from cutting, quickly growth and providing rapid soil stabilization (Bentrup and Hoag, 1998). Willow (*Salix*) has been cultivated for an agricultural crop to many purpose, such as for bioenergy (Perttu, 1998), making baskets, made a tea from the bark and some medical uses (Foster and Duke, 1990).”(scialert.net) Willow's produce a hormone that gives it the ability to grow from cuttings. Willow's hormones are used in nurseries to help other plant cuttings form roots. One major chemical that comes from the the species is Aspirin.(medicinenet.com) This was first discovered by the American Indians who used it as a natural remedy for headaches and fevers. Not only did the Indians use it as a remedy but they made use of the inner bark and branches to weave baskets, make rope, and use it for constructing shelters. The willow trees can reach heights of up to 70ft. tall and range in all shaped and sizes. “Willows are predominantly pollinated by insects, and perhaps partly by wind.”(hoadley.net) However the majority of willows grow from shoots or fallen branches. In their natural environment the willow trees provide a great deal of shade due to their dense canopy. This moderates near by water temperature and surrounding micro climates.(Olechnowski 2008) Willows also play a huge role in habitat stability by providing other species a place to live and function. A few of them include: Sparrows, Flycatchers, Finchs, Swallows, Bumble Bees, squirrels, and various insects.(laspilitas.com)

With all of these benefits coming from the willow there is an immediate need to help restore them back to their natural population numbers. There is no specific data on habitat loss numbers for the willow tree in the state of California however we do know their has been a decline over the past 20 years due to land development and urban sprawl. The positive aspects of initiating a willow restoration movement by far outweigh the negatives. Even small environmental changes like providing more habitats for birds to use as sanctuaries and providing shade for small animals to gain cover in make huge differences the stability of natural environments. Every project has challenges including this one. Some challenges that might come up would be lack of funding for the projects. Much of the open space is privately owned making it more complicated to plant. Weather extremes also play a huge role in seedling development. These are just a few of many issues that can arise during the implementation and lifespan of a willow restoration project.

In order to organize a restoration effort a management plan is needed. The first step is to decide whether the willows will be planted as seedlings or as a more mature tree. Cost is a big factor here as seedlings cost way less than mature trees. The downside to using seedlings is that there is a much higher mortality rate than by planting more established trees.(hoadley.net) Either way it can be a costly effort due to the fact that the surrounding areas around trees need to be maintained, the trees need to be irrigated for up to three years, and the fact that they will need stakes and or bases to hold them in place and to protect them from predators.

Restoration Goals:

The ideal site restoration effort is to have an increase in the overall number of willow trees on site by approximately 20% over the course of a ten year period. (based up site visit approximation) This increase of 20% will roughly provide enough cover to allow natural ecosystems to be repaired and allow for the redevelopment of natural ecosystems. The potential for these goals to be met would not be difficult as the planting and maintenance of new willow trees is not hard to do. The only downside to this goal is the man hours that would be needed to plant all of the new seedlings. The site has many ties to different species like the bumble bee who uses the willow trees as a source of early season nectar. The immediate goals of the site are to plant several willows near the newly restored stream and ponds. This will increase the amount of greenery in each portion of the site where water is present. . The goal is to install and place the willow seedlings in areas on the site that allow for them to gain maximum growth results. Placement in damp and cool environments in a key aspect to location selection.

On a large scale the restoration of the willow tree will mostly aim to restores habitats. After several years of growth the willows will be large enough to provide shade and natural environments for local wildlife including birds and insects to live and flourish in. The goal here is to increase natural wildlife activity in the area through increasing the willow population roughly 20% of the current numbers on site.(site visit approximation) On a smaller scale, another goal is to increase the bank and hillside stabilization of the site. The massive root systems help prevent erosion and reinforce the banks. The willows have dense canopies and provide a great deal of shade. This leads to the cooling of its surroundings and helps keep moisture in the ground. (Grissinger 1984) This leads to high growth rates in these areas. By increasing the amount of willows on site it will help clean groundwater. The trees naturally remove nitrogen from water which will benefit the whole site. Higher water quality will lead to a higher growth rate among other plants and animals.

Restoration Plan

- The willow trees are very difficult to grow from seed so cuttings are the best way of planting. Our best bet would be to have them grown in nurseries and transplanted into the ground after they have established their root systems. Seedlings ideally should be placed in cool moist environments however this is not a necessity. The willow has a hormone that aids in it growth which allows for the seedlings to be planted in almost all ground conditions.

- Seedlings should be planted with space between them to allow for roots to grow in the future. This is a requirement because lack of space between trees will create competition and force their roots to compete for water and nutrients.

- Placing willows near ponds will help them grow quicker. Do not place to close to the water as root systems can choke water holes. Placement of willows along west border of plots one through five will help provide shelter from wind for each plot. Several willows can be placed sporadically across upland area in order to provide shelter for local species.

- “For larger transplants, make cuttings in the summer and plant in a nursery bed when roots are established. Plants can easily grow more than 6 foot (180 cm) per year. Smaller rooted cuttings are useful in stream plantings, enabling you to put in large numbers of plants with little soil disturbance. Cuttings can also be taken in the spring and stuck right in the ground where you would like the plants to grow, although you need moist, protected conditions and can expect less success. Along eroded stream banks, use cuttings up to 3 feet (90 cm) long if the soil is loose enough. Leave only a few buds showing. This allows more roots to form deeper in the soil and helps bind the stream bank together. Cuttings should be taken from many different plants and areas to ensure good establishment of willow beds with wide genetic diversity.”(geocities.com/willowpool/growingwillow.html)

- Seedling can range is size upon planting. Ideally a 12” seedling is our goal. This allows for the plant to be strong enough to stand harsh conditions but also allows for the tree to adjust to the local conditions at an early age. Seedling planting method should include the use of tubes to protect the seedlings from grazing, and other potentially destructive threats.

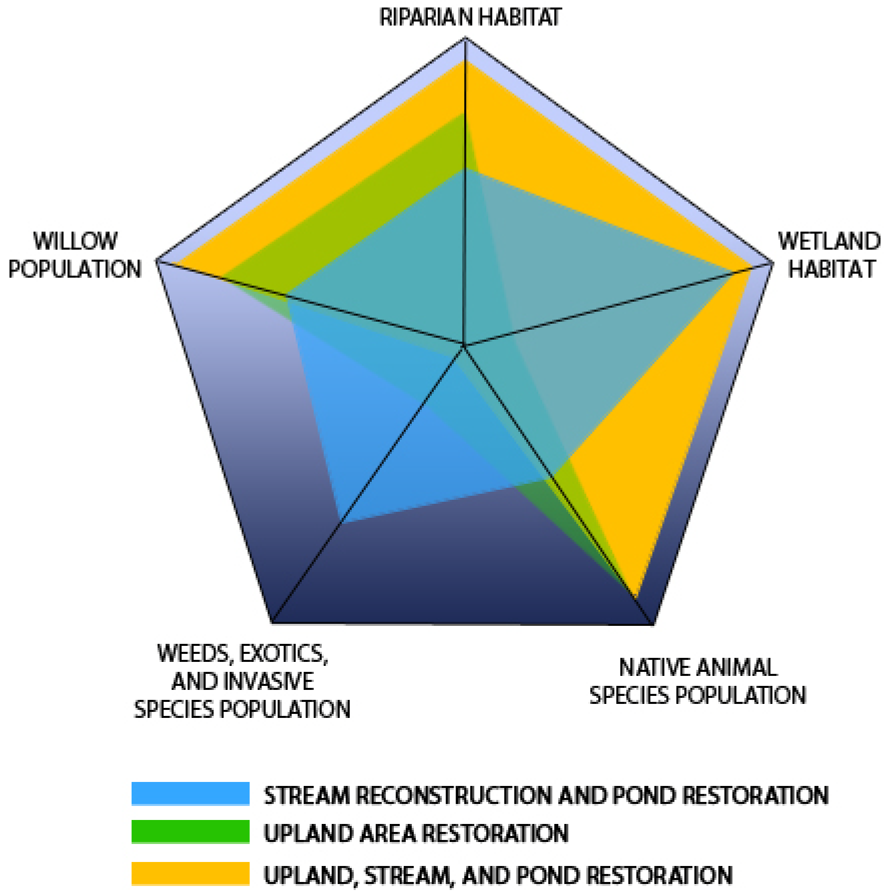
- Over the course of the first year the seedlings should be checked on periodically. The checkups should look to see what the survival rates of the trees are, the growth rate since last inspection, and the coloration of leaves and bark. Looking at these three things will tell us how well the trees are doing on the site. The first three months the tree should be checked on twice a month, after that they should be checked on once a month for up to a year. After a year they should be checked on once every three to six months. These checkups are not required however they will increase the overall survival rate of the trees as a whole.

- Risks and potential negative aspects need to be considered when looking at restoring the natural willow populations include destruction of seedlings during the first couple years through trampling or grazing. Funding can also lead to become an issue in this restoration effort. Purchase of tubes and seedlings can be costly and not to mention the cost of man hours to plant the trees. The site has had fairly moderate weather over the course of the past couple years however in the case of a drought or extreme freeze there is s chance that some of the new tree could be eliminated.

Part III – Managing Multiple Goals

Based upon the goals of some other students I have come to the conclusion that restoring the willow population of our site would only aide all the other species being studied. The willow has very few negative impacts on existing ecosystems and species. I see the willow trees as only improving the site. I will stick with my original plan to strategically place willow cuttings on the site in specific locations. My rationale for my choice in restoration is to provide as much tree cover as possible without be unrealistic in the sense of cost, effort, and time.

<u>Trade off Diagram – Upland vs. Wetland vs. Combo Illustration</u>



Situation #1: Stream Reconstruction and Pond Restoration

In this situation the stream is being relocated to the southern most boarder to increase land for potential riparian restoration. This situation also includes restoring the ponds located on the north of the lot. In this situation the wetlands size and health is greatly increased. This will lead to an increase in aquatic species presence. This will also increase growth of the surrounding species including the willow trees that like growing next to river banks and wetlands. This will also cause a slight increase in the riparian ecosystem and native species associated with the riparian systems. There are some negative aspects in this situation because due to the exotics, weeds, and invasive species lack of removal.

Situation #2 – Upland Restoration

In this situation much of the exotics, weeds, and invasive species are removed and replaced with natural species. This forces an increase in the overall riparian ecosystem, the native species, and the overall willow population. However this contributes very little to the wetlands health and coverage. The negative side to this situation is that it would be a very unbalanced restoration project. The upland area relies on the wetland area to survive so without the water restoration effort, the growth rate of plants and animals may be limited due to lack of water.

Situation #3 – Upland, Stream, and Pond Restoration

This is a win-win restoration effort and is the ideal method. In this situation restoration would occur on both upland and wetland levels providing a multifaceted restoration effort. Due to the two area being so closely related and linked to one another the overall effort provides a much higher growth rates. The native species and willow populations both jump dramatically along with the overall growth rate of the riparian ecosystem. The restoration effort even includes removal of most of the sites weeds, invasives, and exotic species. The negative side to this situation is that it will cost more money and take more time to complete.

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ENH 160
Spring 2009

ENH Class Project - Part I
Blue Elderberry (*Sambucus mexicana)*

The Blue Elderberry (*Sambucus mexicana syn. nigra spp. caerulea*) is a broadly distributed 2-8m tall shrub in the Honeysuckle Family (Caprifoliaceae) (Hickman ed., 1993). It is a common component of riparian forest throughout much of the American west. It occurs in riparian areas throughout California, in nearly every county. *S. mexicana* grows under a relatively broad range of soil types and moisture conditions (Alpert et al, 1999). It provides substantial habitat and food resources for wildlife including pollinators, birds, and the threatened Valley Elderberry Longhorn Beetle (Vaghti et al, 2009). The inflorescences are terminal panicles consisting of cymes, and produce many white flowers in the spring (Hickman ed., 1993). The highly nutritious fruit matures in July and August.

Threats to *S. mexicana*

The primary threat to *S. mexicana* is habitat destruction. Riparian forest has been widely destroyed as riparian areas have been developed for agriculture, irrigation, and flood control (Alpert et al 1999, Barbour et al 1993, Holland and Keil, 1995). It is estimated that of ~900,000 acres of riparian forest that historically existed in the central valley of California, less than 100,000 acres remain (Barbour et al, 1993). That is approximately a 90% reduction in riparian forest habitat. Within the remnant riparian forest, *S. mexicana* is a common feature (Barbour et al, 1993, Holland and Keil, 1995). It is not considered to be a threatened species. However, many species that depend on *S. mexicana*, and other riparian forest members cannot persist in the small, highly fragmented forest remnants. Additionally, the many ecosystem services provided by riparian forest including water filtration, soil retention, and habitat have been lost in the areas where the forest has been destroyed (Alpert et al, 1999).

Ecological Role of *S. mexicana*

1. Sole host plant of the threatened Valley Elderberry Long Horn Beetle (*Desmocerus californicus dimorphus*) (Collinge et al, 2001, Holyoak and Koch-Munz, 2008)
2. Food resource for songbirds (Vaghti et al, 2009, Stevens et al, 2001)
3. Food resource for pollinators (Vaghti et al, 2009, Steven et al, 2009)
4. Historically abundant component of healthy riparian forest in the Central Valley (Alpert et al 1999, Barbour et al 1993, Holland and Keil, 1995)
5. Helps provide bank stability to riparian systems (Alpert et al, 1999)

The *S. mexicana is* important sources of summer food for many kinds of songbirds. Stevens et al (2001) provide a list of many species including, "the western bluebird, indigo bunting, common house finch, red-shafted flicker, ash-throated flycatcher, black-headed grosbeak, scrub jay, Stellar jay, ruby-crowned kinglet, mockingbird, red-breasted nuthatch, Bullock's oriole, hooded oriole, song sparrow, white-crowned sparrow, western tanager, California thrasher, russet-backed thrush, brown towhee, Audubon warbler, cedar waxwing, Lewis and Nuttall's woodpecker, wren-tit, grouse, pheasant, and pigeons all eat elderberries." According to Vaghti et al (2009) *S. mexicana* prived nesting habitat for many birds, spiders and insects. Deer, raccoon, rodents, and bear all utilize *S,. mexicana* leaves and berries as an important summer food source (Vaghti et al 2001). Adult Valley Elderberry Longhorn Beetles feed on the leaves and flowers, while their larva bore through the stems and feed on the stem tissue.

Habitat Specifications of *S. mexicana*:

1. Prefers moist soils, but grows well in drier soils once established (Holyoak and Koch-Munz, 2008)

2. Can grow in wide variety of soil types ranging from sandy loam to clay (Holyoak and Koch-Munz, 2008)

3. Does well in both shade and full sun (Holyoak and Koch-Munz, 2008, Stevens, 2001)

The above points indicate that *S. mexicana* has a wide range of ecological tolerances. While this is true, an analysis of restoration projects addressing riparian forest by Holyoak and Koch-Munz (2008) found that *S. mexicana* grew significantly faster, and produced more and larger stems, when planted in moist, sandy-loam soil in full sun. Since large, mature stands of *S. mexicana* are necessary for fulfilling the full range of ecological functions, these are the conditions that restoration activities should target.

Barriers to Establishment:

1. **Lack of nearby seed sources**

Riparian forests in the Central Valley of California have been widely cleared for the purposes of agriculture and flood control as rivers and streams are channelized (Alpert et al, 1999). The remaining vegetation exists in a patchwork of isolated stands. If no extant patches of *S. mexicana* occur within the dispersal distance of a given site, then there is little change of passive establishment and seeds or transplants must be introduced to the location. A study by Vaghti et al. (2009) found a significant lack of natural recruitment on the Sacramento River and its tributaries.

2. Lack of perches for seed distributing birds

S. mexicana is a valuable food resource for songbirds, and it is assumed that songbirds are a important vector for seed dispersal (Vaghti et al, 2009). Many studies have shown that birds are important dispersal agents, and that providing perching structures can increase the rate of seed arrival and the number of species that reach a given site (Debussche and Isenmann, 1994). Perches are a common strategy employed by forest restoration practitioners, mainly in tropical regions. However, Dubussche ad Isenmann (1994) demonstrated that this is an important mechanism in patchy Mediterranean systems as well. There is know data

3. Competition with Exotic vegetation at the establishment stage

Competition at the recruitment stage with alfalfa has been shown to drastically reduce the survivorship and establishment of *S. mexicana* (Hubbell, 1997 as reported in Vaghti et al, 2009). Competition with alfalfa is not a common issue in restoration projects, but this interaction may be indicative of *S. mexicana* competitive inferiority against exotic ground cover at the establishment stage. Although the competitive interaction of other exotic species, most notably annual grasses but also including Burmuda grass (*Cynodon dactylon*) and Himalayan blackberry (*Rubrus discolor*), have not been directly studied, it is likely that the high prevalence of these species along most riparian areas is a significant barrier to establishment (Vaghti et al, 2009). This is a topic that could clearly benefit form some scientific investigation.

Elderberry and Browsing (Stevens et al, 2001):

- Elderberry is only palatable during the late-summer and fall
- Browsing is not harmful to mature trees with adequate foliage above the browse line, however saplings and seedlings can easily be fatally browsed
- Cattle, sheep and goats will eat elderberry foliage, but native browsers such as deer do not prefer it. Deer will, however, eat the berries that are within reach.

Elderberry and Fire:

There is little information regarding the role of fire in riparian systems, but it is not a major component if these systems. They are resistant to fire because they occur in wet humid conditions. Occasionally wind driven fires will burn into riparian forest, but the fire is unlike to spread along the riparian corridor. Although it has not been addressed in the literature, I do not believe that fire is a desirable or feasible management tool for *S. mexicana*. The *S. mexicana* growth form consists of dense stems that would easily carry a fire into the canopy, which would be highly destructive or perhaps fatal. This biomass destruction would run counter to the goal of creating a large, complex stand of *S. mexicana* in order to support wildlife, and there are no other obvious compensatory benefits.

Valley Elderberry Longhorn Beetle

The Valley Elderberry Longhorn Beetle (*Desmocerus californicus dimorphus*) was federally listed as threatened under the Endangered Species act in 1980 (Holyoak and Koch-Munz, 2008). Contributing factors to its decline are habitat destruction, insecticide spillover from agricultural applications, predation by the exotic argentine ant, and dust deposition resulting from construction and agriculture (Holyoak and Koch-Munz, 2008). Adult beetles feed on the elderberry leaves and flowers. Females deposit their eggs on the stems, and the larvae burrow into the stem, and feed on the stem tissue. Following metamorphosis the beetle bores out of the stem. These bore holes are the most visible record of VELB presence (Holyoak and Koch-Munz, 2008).

D. californicus dimorphus is only found to inhabit approximately 25% of available *S. mexicana* populations (Collinge et al, 2001), suggesting incomplete understanding of the habitat requirements of the beetle, or meta-population dynamics that leave a significant portion of the potential habitats open at any one time. Older bushes with higher proportions of dead stems are far more likely to harbor beetle populations (Hollyoak and Koch-Munz, 2008). Therefore, if it is a goal to establish beetles at a site that currently has no *S. mexicana*, it may take many years for appropriate conditions to develop. For this reason, Hollyoak and Koch-Munz (2008) recommend that monitoring for *D. californicus dimorphus* extend well beyond the 3-4 years that are usually allotted for determining restoration success. Mature plants that already contain beetles can be moved to appropriate sites in order to establish new populations (Hollyoak and Koch-Munz, 2008).

Hollyoak and Koch-Munz (2008) compared mitigation sites where *S. mexicana* stands were established to natural *S. mexicana* populations that contain *D. californicus dimorphus* in order to determine what factors allow for mitigation success. They found that mitigation populations of *S. mexicana* were on average only 24% of the size of natural populations. They also found that beetles were more likely to be found in older, larger shrubs with high percentages of dead stems, and in shrubs that grew in the open rather than under a canopy of other trees. If the establishment of *D. californicus dimorphus* is to be a goal of this restoration project, these conditions should be met by planting large contiguous patches of *S. mexicana* with no overstory vegetation. If possible, some of the transplants should be large, mature individuals. Otherwise, managers should expect to wait until smaller individuals mature before assessing restoration success.

Method of Restoration

S. mexicana can be established on site through direct seeding, planting plugs and cuttings, or transplanting mature individuals from other sites (Stevens et al, 2001). Seeds are available for collection in July and August. Seeds require a period of cold exposure before they will germinate (Stevens et al, 2001). The horticultural team at the Santa Barbara Botanic Gardens have found that allowing the seeds remain in the berries as the fruit ferments also increases rates of germination (Wyatt, personal communication).

To directly seed *S. mexicana* seeds should be distributed at a density of 35 seeds per square foot (Stevens et al, 2001). Stevens et al (2001) recommend burying the seeds a quarter inch below the soil surface, and then distributing a layer of sawdust mulch over the top. Seeds that don't germinate immediately may stay viable in the soil for many years. Seeds can also be started in a nursery and then plugs can be planted out. This method requires a greater initial investment time and resources, but seedling survival rates are much higher, and therefore less overall seed is needed.

S. mexicana can be propagated by cuttings. Stevens et al (2001) state that cuttings should be made from the previous year's growth, be at least ten inches in length, and include two nodes. The stems are placed in Perlite after being dipped in rooting hormone. The major drawback to this method is that the cuttings form weak, fragile early roots that can be easily damaged during the transplanting process. This may result in high mortality of the transplants.

Finally, entire shrubs of *S. mexicana* can be transplanted from one site to another (Holyoak and Koch-Munz, 2008, Stevens et al, 2001). This is desirable for managers who want to quickly establish large individuals, or want to introduce plants that already harbor Valley Elderberry Longhorn Beetles. In order to transplant an adult individual, the shrub must first be pruned to 50 percent of its current size, or to 10 feet in height, depending on which method leaves you with the tallest plant (Stevens, 2001). Then the entire root ball must be excavated, and kept moist while the shrub is transported. The root ball should be planted 3-4 feet below ground level. It is important that the shrub be well watered for the first year following transplantation to allow for the development of a new root system (Steven et al, 2001).

Potential funding sources

Although *S. mexicana* has no special conservation status, it does support VELB witch is listed as threatened under the Endangered Species Act. Under this law, many development projects require mitigation actions to offset potential damage to endangered species. Developers are required to fund these mitigation activities. It is possible that funding for VELB mitigation in the form of habitat restoration, may be provided by UC Davis in order to offset campus development projects. Furthermore, Habitat Conservation Plans (HCPs) allow developers to proactively engage in mitigation activities in order to bank mitigation to offset future development. It is possible that we may receive funding from any number of developers within Yolo County who wish to pursue this option. Yolo county has an informal HCP that is still in the process of being finalized.

There are also many potential sources of funding for riparian restoration projects in general. Many state and federal grants are available for riparian restoration, largely because of the recognition of the societal benefits of functioning riparian forests. Non-profit conservation agencies also offer grants for small-scale restoration projects, and are a potential source of funding.

Part II – The Restoration Plan For Blue Elderberry (*Sambucus mexicana)*

There are two potential restoration options associated with *S. mexicana* depending on whether the creation of Valley Elderberry Longhorn Beetle (VELB) habitat is desirable and feasible. VELB require large contiguous stands of *S. mexicana* that are on average at least 7.5 acres in size. However, this would require that 10-12% of the project site be devoted almost exclusively to planting *S. mexicana,* and this devotion of land to one species comes at the expense of restoring any others. It is up to the project managers to determine whether this is a realistic goal.

Option 1

If VELB habitat creation is a desirable and feasible priority, at least 7.5 contiguous acres of *S. mexican*a should be planted along the riparian corridors provided by the effluent channel and the holding ponds.

Option 2

Otherwise, a more diverse and natural riparian forest community, of which *S. mexicana* is a single component, should be restored in these areas.

Option 1 details:

Stand size and structure are two critical factors for successful VELB. The larvae require large individuals with stems at least 2.5cm in diameter. In order to most quickly achieve these habitat characteristics, *S. mexicana* should be established under the conditions that most favor rapid growth. These conditions include moist, sandy-loam soils and full sun. This means that *S. mexicana* should be planted by itself to reduce light and resource competition with other species. This management option comes at the cost of not restoring a rich assemblage of other riparian shrub and tree species.

Option 2 details:

Riparian forests are among the most diverse forest communities in California (Barbour et al, 1993). *S. mexicana* naturally co-occurs with many species of trees and shrubs including Willow (*Salix sp.*), Fremont's Cottonwood (*Populus fremontii*), California Walnut (*Juglans californica and J. hindsii*), Oregan Ash (*Fraxinus latifolia*), Box Elder (*Acer negudo)*, Valley Oak (*Quercus lobata)*, Bigleaf Maple (*Acer macrophyllum*), White Alder (*Alnus rhombifolia)*, and California Sycamore (*Platanus racemosa*). In addition to these trees and shrubs, riparian forests support a rich herbaceous understory.

It is more likely that a rich assemblage of species in the riparian habitats on the restoration site will provide a broader array of ecological functions including increased water filtration, soil retention, and habitat for animals that require food and shelter resources not provided by *S. mexicana.*

General Guidelines for *S. mexicana* Restoration:

1. **Propagation Methods**

Growing From Seed

Seed Sources:

Seeds are available for collection in July and August. They should be collected from local populations to capture appropriate locally adapted genotypes. Seeds should be collected from multiple individuals, and if possible from several different populations to maximize diversity in the genetic portfolio.

Seed Preparation:

Seeds should be stratified and scarified to increase rates of germination. To further increase germination rates, the seeds should be left to sit in the fermenting berries prior to stratification. Seedlings must be grown in the nursery for one year before they are ready to be planted at the site. Planting should take place in the fall was the rains have begun.

Transplantation

In order to quickly establish large individuals on site, transplanting adult individuals form other sites is an effective propagation method. The entire root ball must be carefully excavated, and kept moist constantly. The root ball should be planted 3-4 feet below the ground surface. Transplant survival is dependent on keeping the plant well watered throughout the first year of growth. Transplanting should take place during the fall once the rains have begun. The time, effort and expense of transplanting large shrubs is a major barrier to this management action. The number of individuals transplanted adult shrubs will be constrained by the project budget and labor force.

Note: Although S. mexicana can be propagated via cuttings, this method is not recommended for this project. Cuttings produce weak root systems and experience high mortality once planted. Cuttings are generally less than a foot tall. Seedlings produced from seeds are far more resilient, and since S. mexicana is a fast growing species, they quickly match cuttings in size.

2. Planting Design

Seedlings should be spaced apart by approximately 10 feet across the entire riparian zones along the effluent channel and the Putah Creek tributary. *S.*

mexicana is a rapidly growing species, and can reach full height in 3-4 years. Larger, transplanted individuals should be interspersed throughout to increase desired stand structure and complexity. If VELB establishment is the goal, some plants likely to contain VELB larvae, taken form patches with VELB populations should be transplanted as well. Stems with bore-holes can also be taken from these populations, and laid on the ground at the base of the transplanted shrubs.

If the managers decide to restore a more natural riparian forest assemblage, the planting regime for *S. mexicana* should be far less dense in order to incorporate other species of tree and shrub. The overall planting density should remain the same.

If grazers are to be used as a management tool for other restoration targets on other regions of the site, fences should be erected to keep them away from *S. mexicana* seedlings, since the seedlings can be fatally browsed when small. Once the stand has attained a height that exceeds the browse line, the fence can be removed. Adult shrubs can withstand grazing.

3. Monitoring

Monitoring Design

A recommended method for monitoring many different targets in the riparian areas of the site is to set up a series of permanent transects, running perpendicular to the stream channel, along which measurements can be taken at regular intervals.

Prior to Restoration

Since there is some evidence than seedling recruitment and establishment of *S. mexicana* is inhibited by competition with exotic species that form dense groundcover such as grasses of Himalayan Blackberry, it is important to monitor the presence. Exotic cover can be measured using a square meter quadrat. Either total percent cover or point intercept data will be useful for describing the extent of exotic cover. Control methods should be used to eliminate or greatly reduce exotic cover prior to planting.

Seedling and Transplant Survival

Seedling and transplant survival can be quantified by counting the number of living and dead individuals within ten feet of either side of each transect. This should be done for the first two years following planting. Initial mortality rates should be assessed in the spring following the fall planting. After that, the annual monitoring should occur at the end of summer due to the fact that the highest mortality will probably occur over the long period over which the shrubs get no water. High mortality rates should trigger supplemental planting. By monitoring in the late summer, managers can get the best sense for what planting must be undertaken in the fall once the rains begin.

Structure

VELB larvae require stems at least 2.5cm in diameter. To assess how quickly the *S. mexicana* stand is converging on the desired structure, the proportion and density (#/m^2) of stems with a diameter greater the 2.5 cm should be measured annually. To assess this, all stems of each individual occurring within 3 feet of either side of each transect should be measured.

Valley Elderberry Longhorn Beetle

VELB adult sightings are exceedingly rare. The most common method for VELB monitoring is to count the exit holes created by recently metamorphosed larvae as they leave the elderberry stem. As noted by Holyoak and Koch-Munz (2008) monitoring for VELB presence should continue for at least ten years before assessing project success. Unlike the other monitoring targets, this monitoring should be a more exhaustive search of the elderberry stand rather than only being conducted along the permanent transects.

Post-Establishment Weed Management

Managing exotic vegetation beneath established *S. mexicana* shrubs poses a particular challenge. It will be difficult to access weeds that grow amongst the dense stems, and some weed control methods pose some risk to the shrubs themselves. However, it is a challenge that is must be met in order to ensure that *S. mexicana* seedlings can establish in order to replace older individuals as they senesce, and that weeds that find refuge beneath shrubs do not re-invade other areas. It may be impossible to entirely eradicate exotic species form *S. mexicana* stands, but a combination of control methods can be used to keep them in check. Manual removal and selective grazing are probably the best options. Where herbicides must be used, particularly to control Himalayan Blackberry, the should be manually applied to cut stems to ensure that *S.*

mexicana is not negatively impacted.

4. Summary of Recommended Management Strategies

1. Plant seedlings grown from locally collected *S. mexicana* populations
2. Controlling exotic annual grasses populations using best management practices

For most successful execution (i.e. most rapid growth):

3. Plant seedlings in full sun
4. Plant seedlings in soils with intermediate moisture
5. Plan seedlings in sandy loam soils

To encourage inhabitation by the Valley Elderberry Longhorn Beetle:

6. Plant large, contiguous stands (The mean size of natural stands inhabited by the beetle is 7.5 acres)
7. Again, do not plant *S. mexicana* as an understory shrub beneath the canopy of other tree species.
8. Transplant at least some large, mature individuals with a higher proportion of dead stems
9. Transplant some individuals that already contain Valley Elderberry Longhorn Beetles.
10. Continue monitoring for beetles beyond the usual 2-3 years used to determine project success as it often takes 10+ years for the stands to develop the appropriate size and structure.

Part III – Revised Plan considering other management objectives

The management plan collaboratively developed by our restoration (ENH 160) class has deemed that the uppermost pond be devoted to the restoration of herbaceous riparian vegetation. This is necessary to meet several important management goals, however it does diminish the area suitable for *S. mexicana* restoration. For this reason, I recommend that we implement management option 2 in which a diverse riparian community is established along the effluent channel and lower pond. This is because option 1, designed to create viable habitat fro the valley elderberry longhorn beetle, requires the establishment of a minimum of 7.5 acres of mature *S. mexicana*. Without utilizing all potential riparian areas, it is unlikely that this size stand can be achieved.

Option 2 is well compatible with other management options. The successful eradication of riparian weeds such as Himalayan Blackberry an essential component of successful *S. mexicana* establishment. This plan is also compatible with restoring other woody riparian targets including Valley Oak and Willow, and does not directly conflict with other management goals. It is possible that some of the management actions executed before the establishment of *S. mexicana* could compromise the ability of successful establishment. For example, and heavy machinery used to clear exotics such as Himilayan Blackberry could compact the soil. *S. mexicana* prefers well drained, moist soils, so this could limit its survival and growth rates. However, this effect would most likely be temporary and limited in scope.

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Native grass species

A. Background & Justification: *Hordeum brachyantherum* Restoration

Goal: This paper investigates the best restoration strategies to encourage the establishment of *Hordeum brachyantherum* (Meadow Barley) in a restoration project in Davis, California.

Background: *Hordeum brachyantherum* is a perennial grass native to Western North America, from Baja California through the Aleutian islands of Alaska. It grows in tufts, 25-90 cm tall, with purplish green or green bloom spikes 30-85 mm long (von Bothmer et al. 1991). Its range extends from the Pacific coast east to Idaho, Utah, Wyoming, and Colorado (von Bothmer et al. 1991). The USDA PLANTS database also includes many northeastern states in the range of *H. brachyantherum* (USDA, NRCS 2009). It thrives in a variety of habitats, including salt marshes, pastures, subalpine meadows, and woodlands. The ability of the species to thrive in a variety of habitats (as opposed to just grasslands) is rare even within the genus *Hordeum* (von Bothmer et al. 1991). It is a very common species, and is often dominant in pastures. It reproduces predominantly through self fertilization (von Bothmer et al. 1991).

H. brachyantherum grows actively in spring and summer, and is slow to regrow after it is grazed or harvested. It is adapted to coarse, fine, and medium textured soils, and has a high anaerobic tolerance. It is moderately drought tolerant, preferring a range of precipitation between 20 and 80 inches/year (USDA, NRCS 2009). It has low soil fertility requirements and is moderately tolerant of salinity. It is intolerant of shade. It can be propagated only by seed, and its seeds are not persistent (meaning they last for less than one year, USDA, NRCS 2009). In some regions of the US, including California, it is a facultative wetland species (67-99% of occurrences are in wetlands), while in others it is just as likely to be found in or out of wetlands.

Justification: *H. brachyantherum* is potentially useful as a vegetative buffer between agriculture and riparian areas. It establishes quickly, so it is often used as temporary groundcover to prevent erosion, or as a nurse species for other slower-growing native species in drier areas. At maturity it is not good forage for grazing animals, but it is useful to wildlife as cover and its seeds are palatable (Darris 2006).

Potential policy and funding sources: According to the USDA PLANTS database, it is neither threatened or endangered. Therefore, there will be hardly any policies regarding this species, and it will not be a priority for funding from conservation sources like California Native Plant Society or National Fish and Wildlife Service. *H. brachyantherum* is a wetland indicator species, and its use as a wetland indicator might implicate it in the complicated policy ecosystem that envelopes wetlands. This connection to wetlands may allow it to be used in restorations for wetland mitigation mandated by California and Federal Laws.

H. brachyantherum is a congeneric relative of the important food crop barley, *Hordeum vulgare* (von Bothmer et al. 1991), and therefore might be useful in breeding to improve genetic diversity and disease resistance in barley or other cereals (see discussion of diseases below). Hence, organizations interested in food security and crop genetic improvements (FAO, etc.) might support the maintenance of healthy populations of *H. brachyantherum.*

B. Literature Review

Main factors-*Biotic*: Perennial grasses are often adapted to moderate levels of grazing, which helps them maintain maximum productivity and reduces the build-up of dead plant material (thatch) that, if allowed to accumulate, could change conditions enough to favor other plant species (thatch acts as a moisture collector and adds nutrients to the soil, and dry thatch is fuel for fires, Gibson 2009). *H. brachyantherum* might not fit the general rule that grazing is good for grasses; it is moderately good forage when it is a young plant, but then poor forage when it is mature but it is eliminated by close mowing early in the growing season. Moreover, compaction by heavy grazers could damage it, especially on moist sites (Darris 2006). It can tolerate light grazing (OSU 2005) It will be sensitive to grazing timing, type, and intensity. The best time for grazing would be late in its growing season.

Abiotic: The fact that *H. brachyantherum* is spread over such a large range, in many different ecosystems, suggests that it is adapted to a wide range of naturally occurring abiotic conditions, and it MAY be able to persist under the changing temperature and precipitation regimes that are a result of global climate change. However, it is probably not suited to artificially elevated Nitrogen levels (see Rein et al. below).

Fire: H. brachyantherum is “highly tolerant” (Darris 2006) or “unaffected” (Clark and Wilson 1998) by prescribed burning, but specifics are not given as to the timing of the burning. Since it is vulnerable to grazing early in the growing season, I would reason that it is also sensitive to fire at that time.

Summary of research pertaining to *H. brachyantherum*: The keywords *Hordeum brachyantherum* only results in 96 finds on the ISI Web of Knowledge. The bulk of restoration research pertaining to *H. brachyantherum* has been on using diversity to minimize invasibility, the relative competitiveness of non-natives versus natives, vegetative buffers around agricultural fields, and susceptibility to disease (probably because it is a relative to the agricultural crop barley).   These results are summarized below.

Minimizing Invasibility with Diversity: In California’s central valley, a major restoration challenge is that non-native annual grasses sprout earlier and grow faster than native perennial grasses, preventing the establishment of the perennials from seed when they are in a competitive situation (Seabloom et al. 2003). Lulow (2006) investigated the invasibility of established plantings of native grasses with different levels of species/functional diversity in an experiment carried out at the UC Davis Experimental Ecosystem. She followed common restoration practices for reducing competition from annuals.[1] *H. brachyantherum* was found to be significantly less resistant to invasion than *Melica californi*a, in fact it had nearly 100% mortality in all experimental plots. Other native species *Nassella pulchra, Elymus glaucus, and L. tritigoides* did well in competition with non-native annuals, obtaining higher biomass than the non-natives after five years[2]. None of the diverse native-grass mixtures were less invasible than the most successful native species in monoculture. The extremely poor performance of *H. brachyantherum* was not explained by the author, and is worrisome because the location of this experiment is very close to the proposed restoration site.

In Carmel Valley, CA (central coast) Pothoff (2005) also found that *H. brachyantherum* failed to establish itself and have any significant aboveground biomass after five years in a restoration experiment where it was planted in mixtures of native species (*Nassella pulchra, Elymus glaucus,* and *Hordeum brachyantherum*) where non-native annuals were not controlled after planting (although they were removed from the initial seedbank by repeated tillage and herbicide for two years prior to planting). The author suggests that if the non-native annuals were controlled, *H. brachyantherum* might have done better.

Relative competitiveness Kolb et al. (2002) examined the patterns of invasion of California native grasslands by non-native annuals. They focused on two species- the non-native annual *Lolium multiflorum*, and *H. brachyantherum* . They found that non-native plants dominated nitrogen and water-rich spots in the landscape, and that native plants were more competitive with the non-natives in low-nutrient conditions (only if the natives were given a 10-week head start) but not low-water conditions. These results suggest that restoration attempts must remove excess nitrogen, supply adequate water, and control the annual grasses in order to give *H. brachyantherum* priority in establishment.

[1] disced the site and applied Round-up prior to planting 4-month-old grass plugs, and then applied a broadleaf herbicide to reduce competition. Mowed the plots in the second year prior to the ripening of the annual plant seed.
[2]Differences in biomass and reproduction type (rhizomes favored) had a larger impact on invisibility. She concludes that priority effects are important, and warns that data should be collected for more than three years because the outcomes of competitive interactions change over that long a time frame with native grass species.

Vegetative Buffers: H. brachyantherum was used in an attempt to establish native grasses in vegetative buffers for agricultural lands in the Elkhorn Slough Watershed, CA (central coast), by Rein et. al (2007).

They planted native perennial grass species[3] individually and seeded with 50% and 75% of a non-native annual[4]. *H. brachyantherum* performed better than the other native species in the mix, reaching 63% cover. This suggests that *H. brachyantherum* is a robust species for restoration. Perennial grasses showed a significantly higher cover when only perennials were seeded (as opposed to in mixes with annuals). However, after the first two years, the sites became dominated by other non-seeded non-native species, presumably due to the continued inputs of nitrogen from the nearby agriculture and seed rain from the surrounding area. The study concluded that it would be difficult to maintain perennial grasses in agricultural vegetative buffers[5].

Disease. *H. brachyantherum* was found to be susceptible to barley yellow dwarf virus (BYDV), a virus that is a major concern on agriculturally grown barley. When *H. brachyantherum* is weakened by BYDV, it is less successful in competition with non-native annual grasses (Malmstrom et al. 2005). On the other hand, Rubiales et al. (1996) found that *H. brachyantherum* showed signs of resistance to rust fungi, which is a harmful disease for cereals. I think it is unlikely that barley diseases will be common in our restoration site, since barley is not a popular local crop, however it will be something to monitor.

Summary of research results: The literature review shows that restoration experiments with *H. brachyantherum* have had mixed results. Outcomes are probably highly dependent on site characteristics. It is important to control soil fertility to keep it at low levels, and to attempt to give *H. brachyantherum* seedlings temporal priority over non-native grasses and other perennial grasses, which may out-compete it. The key knowledge gap regarding

[3] *H. brachyantherum , Bromus carinatus, and Elymus glacus*
[4] *Hordeum vulgare* and a mix of *Lolium multiflorum* and *Vulpia myuros*
[5] The study also concluded that differences between sites were very likely in restoration and suggested that experiments be replicated on many sites before general conclusions could be made.

restoration with this species is how to maintain populations over the long term.

C. Goals for *H. brachyantherum* restoration

The overarching restoration goal is to establish and maintain a stable, reproductive population of *Hordeum brachyantherum* that coexists with a diverse mixture of other plant and animal species. Table 1 gives the more specific goals for the different phases of restoration. *H. brachyantherum* can tolerate a range of soils as long as they are moist (USDA, NRCS 2009), so the moist parts of the site are potential areas for planting.

Potential to Establish and Persist It has performed poorly in many restoration experiments (Lulow 2006, Pothoff 2005), but other sources claim it is hardy and easy to establish (Darris 2006). The outcome will depend on thresholds, tradeoffs/interactions, and feedbacks, and we will need to carefully monitor its performance and make adaptations to the strategy.

Thresholds. Water and nitrogen levels will probably be critical in determining the outcome of *H. brachyantherum*'s interactions with other species. Preliminary soil analysis at the restoration site suggests that nitrogen levels are low, but they still might be too high for this species. It can tolerate moderate levels of salinity, alkalinity, and flooding (USDA, NRCS 2009). Any of these factors might be exploited to help *H. brachyantherum* compete with other species. However, grazing early in the growing season will severely limit the growth of *H. brachyantherum*, and probably lead to its disappearance from the site. At other times it is unpalatable and will tolerate low levels of grazing (Darris 2006). It is probably tolerant of fire (Darris 2006), although a fire early in the growing season may be detrimental like grazing at that time.

Tradeoffs/ Interactions. ***Plants*** *H. brachyantherum* will be in competition with a few restoration target species that fill similar niches, particularly *Leymus triticoides* in the wetter riparian areas and *Bromus carinatus* in the drier (but still moist) upland sites. Because it likes full sunlight (USDA, NRCS 2009), *H. brachyantherum* will not grow under riparian trees (willow, blue elderberry). I predict that *H. brachyantherum* will coexist well with native forbs, since there will be spaces between the bunches for the forbs to establish. However, nitrogen fixing species such as lupines should probably not be grown in the same area as *H. brachyantherum* because of its failure to compete at high nitrogen levels (Kolb et al. 2002). *H. brachyantherum* will probably have trouble competing with exotic invasive grasses, which will need to be controlled.

Animals *H. brachyantherum* would provide good streamside habitat for the giant garter snake and the western pond turtle, because it will be sparse enough to allow these reptiles to bask in the sun. Maintaining *H. brachyantherum* along streamsides will require careful control of topography/hydrology and other aggressive riparian species. *H. brachyantherum* will provide habitat and forage for voles, which are the major food source for the white tailed kite and swainson's hawk.

Feedbacks. If the nitrogen levels increase, other species (e.g. invasive grasses or more competitive native species) will produce more vegetation and be more competitive, and when their vegetation decomposes it will further enrich the nitrogen levels on site, making it even less suitable for *H. brachyantherum* (positive feedback with negative impacts).

Table 1. Specific goals throughout the restoration process for restoring *H. brachyantherum*.

Goal	**Actions**	**Spatial**	**Temporal**
Site Preparation	Remove nitrogen fixing plants from planting area	Planting area, N sources around it	Prior to planting, continuous if an N source remains
Planting	Direct seed (seed from diverse but local i.e. within 150 miles in Central Valley sources) ~30-50 seeds per square foot (Darris 2006)	patches in sunny stream edges and wet depressions	Plant seeds in Fall or early spring (Darris 2006)
Establishment	60% germination is average (OSU 2005). Will probably only establish in suitable sites.	will only establish in suitable sites	21 days to germinate (Young 2001)
Maintenance	Control non-natives if they become a problem- grazing/mowing will be difficult (compaction, mortality), burning is a possibility May be necessary to control more aggressive native species also	As necessary	Prior to planting/germination, and during growing season
Longevity	Monitor to determine if plants are re-seeding themselves. Will only persist in suitable sites. If they do not persist, site conditions might need to change (further nutrient removal, irrigation).	Random sampling within restored areas	Should be able to tell in 2-3 years

D. Restoration Plan

Methodologies

Table 1 gives planting density/genetic source specifications as well as spatial and temporal aspects of the restoration plan.

Configurations of Introductions: Spatially, the riparian areas need to be split up between forest and grass/forbland, then the grass/forbland will need to be further divided among the three major moisture loving restoration target grasses (*Leymus triticoides, Hordeum brachyantherum,* and *Bromus carinatus*). *H. brachyantherum* has not performed well when planted with other native grasses (Lulow 2006, Pothoff 2005), so separating the three moisture-loving native grass target species into distinct bands along a topographical gradient from wet to dry, with *H. brachyantherum* in the middle, might help it persist (illustration A in Figure 1). In contrast, planting large (~5m) patches of the species in a mosaic along the topographic/moisture gradient would give all of them exposure to the different water levels (illustration B in Figure1), but I still recommend spatial separation.

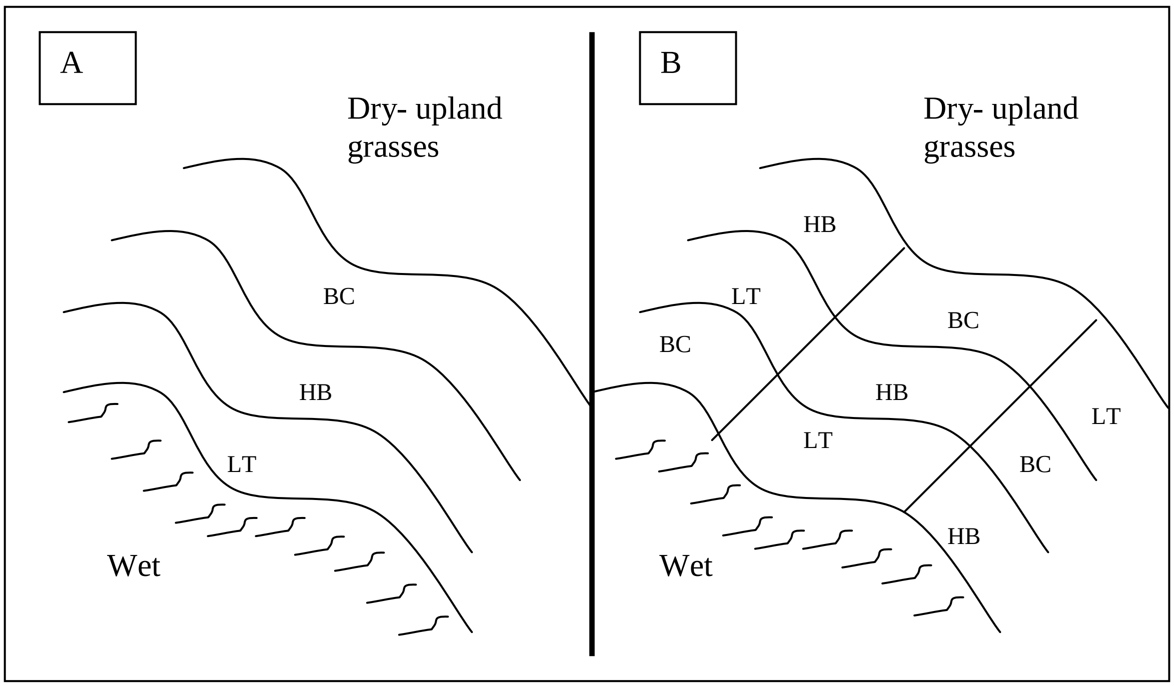

Figure 1. Diagram of spatial separation of three grass species(LT *Leymus triticoides*, HB *Hordeum brachyantherum*, and BC *Bromus carinatus*), along a topographic/moisture gradient represented by contour lines. Either simple separation at the three levels (A) or with all three represented by plantings within all three topographic/moisture levels (B).

Maintaining *H. brachyantherum* in the wetter areas (especially streamside, to provide basking habitat for the giant garter snake) will require control of both *L. triticoides* and invasive riparian species like Himalayan blackberry and yellow-flag iris. A steep, raised streambank would help reduce the moisture content of the soil and make *H. brachyantherum* more competitive. Varied topography (i.e. steep versus gradual versus terraced banks) is important to the coexistence of the many riparian species.

Disturbance Regimes: H. brachyantherum will tolerate some grazing, fire, and flooding (Darris 2006), but it is not obligately adapted to any of these distrubances. If a disturbance regime can be used to control competition from invasive plants, it would be beneficial for it.

Monitoring techniques

Pre Restoration Ideally, the post-restoration annual monitoring should be done both prior to restoration, and after site preparation but before planting. A twice a year walk-through to estimate the common species and their abundance would be the minimum.

Post Restoration: Permanent monitoring transects should be established through representative portions of the site, for example along the gradient from wet areas to uplands and across upland portions. Species composition can be measured along these transects using point-intercept method. Permanent $1x1m^2$ quadrants can also be set up at botanically interesting points along the transect (for example, competition or interplanting zones). This monitoring will inform management by showing which of the target plant species are persisting, how their abundance is changing, and if any invasions by non-natives are occurring.

Spatially explicit data: The edges of the patches of different grass components and the riparian forest edges should be recorded with a GPS every year to give a coarse scale estimate of the competitive performance of the different species.

Temporal scale: Sampling in multiple seasons is ideal for capturing the full suite of species, at least until you can estimate how much the extra sampling effort increases the amount of species you are able to monitor and make a cost-benefit decision. Monitor for five consecutive years to see if the species will persist, then periodic monitoring every 2-5 years as funding allows after that.

Potential problems and adaptations

Although I propose keeping *H. brachyantherum* separate from other species so that it will establish, this will create small monocultures, which might be more susceptible to disease outbreaks because they provide more potential hosts in a small area. This would be a particular concern if cereal viruses are present in the surrounding area. It may require special management for disease control, or its natural resistance (Rubiales et al. 1996) might be enough protection. Even if it is spatially separated from other species, *H. brachyantherum* might get squeezed out by encroachment from other species. In this case we might manipulate the water/nutrients at the site or introduce disturbance. Even with these interventions, it may only be able to persist in a fraction of the area, or not at all. However, it is not labor-intensive or expensive to plant (seeds cost about $30/lb, Larner Seeds 2009), so it is worth a try. There is a small chance that it will be weedy in the wetter areas (Darris 2006) although I think that other species on site (yellow flag iris, *L. triticoides*) would be more likely to do that. Regardless of which species is weedy, regular thinning of riparian vegetation will probably be necessary to maintain the waterway.

Research questions that will be addressed by the plan

Will the native grasses be able to coexist given our planting strategies (topographic strips or intermixed patches)? Will they persist? Will they resist invasion by non-native species? Does modifying streambank topography change the relative abundance of species along a gradient away from the stream?

It would be possible to test these questions with careful restoration design and the described monitoring plan, but it would be impossible to replicate the experiments within the site. True replication would require multiple sites.

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California Brome Restoration
ENH 160
Ben Janes

Part I

Background and Justification:

California brome (*Bromus carinatus* Hooker and Arnott, also known as mountain brome) is an annual or perennial C3 bunchgrass with a wide distribution throughout western North America. Within the state of California, California brome can be found in a variety of habitats between sea level and 3500 m (Hickman 1993). California brome has been widely used in range management because of its good forage quality, relatively high growth rate, and drought tolerance (Plummer 1943, USDA NRCS 2007). Because of its drought tolerance, California brome has also been commonly used for slope revegetation and erosion control (USDA NRCS 2008). Within our local area, California brome foliage and seed is likely to be utilized as forage for geese, other birds, and various small rodents (USDA NRCS 2008). In our restoration site, California brome can be used as one component of the target restored natural community. The same properties and functions that make this species desirable for range and slope revegation projects will add functional components such as drought tolerance, herbivore food source and habitat to our restored site. However, the ultimate restoration plan clearly must attempt to rebuild a community structure rather than focusing on any particular individual species.

California brome has been intentionally or unintentionally introduced to foreign habitats worldwide. In some places the spread of this species has become a management concern, though in others it is viewed as an improvement in rangeland forage quality – particularly in drought-prone systems (Harkess et al. 1990, Chancellor and Froud-

Williams 1986). California brome has been listed as a weed in the U.S. and is often considered a threat to agricultural production (USDA NRCS 2007). However, some local populations within its native range have been out-competed and suppressed by exotic invasive grasses or native woody species (Kolb and Alpert 2003, Vale 1981). It is worth considering the superior competitive ability of California brome when planted with other native plants, and the effect this competitive ability may have on hindering establishment of all components of a diverse grassland community assemblage (USDA NRCS 2007).

Literature Review:

Factors affecting germination, emergence, and early seedling development of *B. carinatus* have been studied since the 1940s. Germination rates and time to germination of California brome can be reduced under cooler and more variable temperature treatments (Plummer 1943). In general, however, California brome has been found to be exceptionally cold tolerant, mostly due to its delayed emergence from seed in late winter (Frischknecht 1951). Perhaps in part due to its relatively heavy seed (*B. carinatus* was measured at 90 seeds per gram, as compared to the mean of the twelve rangeland grasses studied by Plummer (1943) of 841 seeds per gram), seedling emergence was found to be unaffected by planting depths up to the maximum depth used of 1.5 inches (Plummer 1943). In the same study, germination and emergence were high at all experimental seeding depths except for surface seeding. This result was likely also a product of the favorable soil moisture conditions found in this greenhouse study – under field conditions a shallow, quickly drying planting depth is likely highly undesirable for germination and emergence. California brome also showed relatively rapid and extensive root development. Because of its later emergence, rapid root development is a likely competitive adaptation (Plummer 1943). In addition, the high root:shoot ratio of California brome increases its tolerance of drought conditions.

California brome has been shown to perform well under a wide variety of abiotic conditions (USDA NRCS 2008). It regenerates fairly rapidly following fire with limited reductions in abundance (USDA NRCS 2008). Biotic constraints to successful California brome restoration include heavy grazing, infection, seed predation, and competition from invasive exotic species (via multiple potential invasion mechanisms). While light to moderate grazing can favor California brome performance, it is sensitive to the trampling associated with heavy grazing pressure (USDA NRCS 2008). *B. carinatus* has a high degree of resistance to most strains of mildew (Braverman 1967). Hardison et al. (1959), however, reported incidences of *B. carinatus* becoming infected by the fungus dwarf bunt (*Tilletia contraversa* Kühn). Dwarf bunt effectively reduces culm length and alters spike morphology. These changes could alter both competitive ecological interactions (for instance, light access) and reproductive output. Because dwarf bunt is a problem primarily at moderate to high elevation areas with snowfall (CIMMYT 2009), it seems unlikely that incidence of dwarf bunt in the restoration site would cause a constraint to California brome success. A more realistic concern is infection by the fungus head smut (*Sporisorium reilianum*), a disease that *B. carinatus* is particularly susceptible to (USDA NRCS 2007). Fungicidal treatment of seed prior to planting is an effective control of head smut (USDA NRCS 2007).

Another pertinent factor for persistence of the California brome population is consideration of factors affecting naturally dispersed seed success. While methods used for initial seeding of the site will presumably have fairly high success (assuming no major impediments like inability to keep seeded soil moist until emergence), longer term persistence is reliant on natural recruitment. Pollination is unlikely to be constrained, as California brome is capable of self pollination (Smith 1944). However, naturally dispersed seeds face a number of possibilities other than germination and establishment. Clark and Wilson (2003) investigated fate of dispersed *B. carinatus* seeds under field conditions. Averaged over two years of data, only 11% of dispersed seeds germinated and established to a seedling life stage. Approximately 77% of seeds died, with the majority of this death (66% of all seeds, averaged over two years) being attributable to causes that were not measured in the study. Of the three causes of seed death that were quantified – vertebrate predation, fungal infection, and non-viability – vertebrate predation accounted for the largest proportion of seed deaths (21% of all seeds, one year of data). None of the California brome seed persisted in the seed bank. The same large seed size that allows for California brome's rapid initial root extension and shoot emergence has a tradeoff with likelihood of predation due to ease of capture and a decreased ability to penetrate ground surfaces (Clark and Wilson 2003). While one goal of this restoration will inevitably be provision of habitat for small native herbivores, we will need to consider the balance between herbivore presence and long term persistence of certain target plant species.

Given the issue of exotic annual invasion in California perennial grassland systems, much of the literature is devoted to mechanisms of invasion and how these mechanisms can be addressed in a restoration setting. Recently, Borer et al. (2007) have suggested that infection of perennial grassland systems by the pathogen barley yellow dwarf virus (BYDV) is a necessary precondition to facilitate successful invasion by annual exotics. If this is the case, it is clear that BYDV must be ubiquitous in all California grassland systems! While perhaps future management techniques will be capable of immunizing restored systems against pathogens or preventing pathogen migration into said systems (several species of aphids are responsible for transmitting BYDV infection), we currently lack the ability to control for such things within a natural setting without causing excessive damage from insecticide spraying or other control measures.

Nevertheless, maximizing resistance to invasion in any grassland restoration setting needs to be a priority. A recent study of the role of native species identity in resisting community invasion showed an insignificant or even facultative effect of *B. carinatus* presence on invasion success by one invasive perennial grass, *Holcus lanatus* L. (Thomsen and D'Antonio 2007). This coastal prairie invader, however, is of no concern for invasion at our particular restoration site. In another study system, nitrogen availability was shown to have little effect on the competitive outcome between *B. carinatus* and a related non-native competitor, *Bromus diandrus* Roth (Kolb and Alpert 2003). This is in opposition to the often cited assumption that increasing resource levels favor invaders in direct competitive interactions.

At least one restoration experiment has incorporated *B. carinatus* into its suite of planted community members. Bugg et al. (1997) assessed various planting arrangements and site treatments for use in California roadside restoration. These restorations have the primary management objectives of minimizing erosion and siltation, flooding, and fire risk. The following method was used for grass seedling establishment at experimental plots located at Hedgerow Farms, Winters, CA:

- Grader used to prepare seedbed in late fall
- Glyphosate application following early winter (late December) rains
- Broadcast seeding in mid-January with incorporation to a depth of 1.25 cm using a tractor-drawn spike-tooth harrow
- Additional glyphosate application in late January to remove remnant vegetation prior to perennial grass seedling emergence

Despite the presupposed non-selectivity of glyphosate, mountain brome has been shown to be somewhat tolerant to glyphosate, at least under some conditions of application (Ralphs et al. 1990). In the Bugg et al. (1997) design, *B. carinatus* was planted both in monoculture and in perennial mixes. In monoculture, a seeding rate of 22.42 kg seed per ha yielded a germination rate of 88% and an initial density of 322 germinants per m^2. In mixes, *B. carinatus* was seeded at rates ranging from approximately 5 to 16 kg seed per ha. In all experimental applications, *B. carinatus* performed very well in comparison to other study species in terms of both establishment and persistence (Bugg et al. 1997). Similarly, NRCS recommends a seeding rate of 8-10 lb per acre (1.12 lb per acre = 1 kg per ha), or 1-3 lb per acre in mixes with less competitive grass seeds (USDA NRCS 2007). There is some evidence that earlier fall seeding can increase growth and development following germination and induce flowering and fruiting in the first year of growth (Frischknecht 1951). However, this study was conducted under sub-alpine plateau conditions that are considerably different from our restoration site. In any case, establishment of *B. carinatus* should not be difficult, so long as a sufficiently high seeding rate is used and seeds used for planting have a predictable germination rate.

Part II

Goals:

The goal of this restoration plan is to restore a viable, reproductive population of *Bromus carinatus*. An important component of this goal, however, is that establishment of *B. carinatus* should not be at the expense of the establishment of other species. It will be necessary to use low seeding densities or plant *B. carinatus* in patches that are distinct from other herbaceous species being seeded in. An established population of *B. carinatus* should aid community-level resistance to establishment of undesirable invasive exotic species. An additional component of this goal is to minimize cost of implementation. For this reason, it is suggested that *B. carinatus* should be planted into the site from seed, rather than from more expensive transplanted seedlings. Germination rates of *B. carinatus* seed vary from 46 - 85% depending on conditions, which even at the lower end should be sufficient for establishment at the restoration site depending on seeding rate (USDA NRCS 2008). Because of the wide range of conditions under which *B. carinatus* has been shown to thrive, it can be considered as a component species in any of the restoration site's abiotically distinct habitats.

Once established, the goals for *B. carinatus* restoration will switch to issues of controlling its spread and competitive dominance. One aspect of this is to minimize the spread of the population to any adjacent agricultural fields where *B. carinatus* would be considered a weedy competitor with crops. This goal could perhaps be facilitated by focusing most of the *B. carinatus* restoration in the center of the restoration site, or on site edges that are not situated adjacent to agricultural fields.

Management within the restoration site could be needed to keep *B. carinatus* from becoming competitively dominant. This could be difficult, as California brome seems to respond positively to management treatments like fire and light to moderate grazing (USDA NRCS 2008). However, seed predation by wildlife – particularly small rodents and birds – on the restoration site should help to control seed abundance (Clark and Wilson 2003). The large size and high nutrition of *B. carinatus* seeds relative to other grass species makes them a desirable food source for seed predators. Therefore, a principal component of *B. carinatus* restoration should be the restoration of wildlife in the same vicinity.

Restoration Plan:

1. *Seed selection process* – Seed can either be purchased or collected from local sources that closely approximate the conditions of the restoration site. If purchased, seed grown from a local source or from 'Northern Cal 40' Germplasm should be selected (USDA NRCS 2008). Hedgerow Farms in Winters, CA also has *B. carinatus* seed for sale that originated in the North Central Valley bioregion. Though seed collection is more time-consuming and potentially as expensive as purchasing seed (due to transportation and labor costs), natural seed stock has higher germination rates than commercial seed stocks (USDA NRCS 2008).

2. *Seed treatment* – Prior to planting, seed should be treated with fungicide to prevent head smut and infection by other fungi. Captan or Vitavax are two fungicide products that can be used to protect grass seed against fungal infection (University of Illinois Extension 1990). This will probably help to improve germination rate and will greatly decrease the incidence of infected plants, leading to higher productivity.
3. *Seeding density* – If *B. carinatus* seed is planted in mixture with other native grass seed, careful consideration needs to be given to using a low enough seeding rate so as not to competitively exclude the other mix species. If in a mix with species that are not particularly competitive (for instance, slow seedling emergence and low relative growth rates), a seeding rate of 1-3 lb of seed per acre is recommended. An alternative plan for minimizing competitive interaction between *B. carinatus* and other target species is to spatially separate the areas planted with each species. In this case, patches of *B. carinatus* seed could be interspersed among patches of other native species. If planted in monotypic stands, a seeding rate of 8-10 lb of seed per acre should be used.
4. *Selection of planting location* – Because of California brome's rapid rooting, it would be a good choice for planting locations at the restoration site that may be prone to erosion (basin slopes or roadside slopes). Locations close to agricultural fields are undesirable for planting, as *B. carinatus* seeds may escape the restoration site and become a problem weed in agricultural systems. *B. carinatus* should be capable of establishing at all locations in the restoration site except for those that are very poorly drained (Basin 1 and riparian areas).

5. *Site pre-treatment* – Prior to planting, the seedbed can be prepared using a grader or other mechanical means. Efforts should be made to clear unwanted existing vegetation. Roundup (glyphosate) application is an herbicide that is commonly used as a site pre-treatment for vegetation removal. Because *B. carinatus* has demonstrated resistance to roundup treatment, local applications to any undesirable invasive species after *B. carinatus* emergence can be expected to have little to no effect on California brome individuals (Ralphs et al. 1990).
6. *Planting method* – Planting of seed should take place in early to mid winter (rainy season). Earlier planting can induce flowering and fruiting during the first year of growth, which may or may not be desirable at the restoration site (Frischknecht 1951). For instance, it may be desirable to try to induce first year seed production in some fraction of the restored *B. carinatus* population in order to provide a food source for other component species at the restoration site. A general rule of thumb for planting seed is to bury the seed to a depth that is twice its diameter (USDA NRCS 2008). However, *B. carinatus* can establish successfully when its seeds are planted as deep as 1.5 inches (Plummer 1943). Mechanical means could be used to plant seed without much risk of having seed being incorporated too deeply into the soil. However, mechanical sowing could be undesirable in basin bottoms, where soils are already somewhat compacted. Following planting, soil moisture should be maintained at least until emergence. If rainfall is insufficient in the weeks prior to emergence, supplemental watering may be necessary.
7. *Monitoring* – Short term monitoring should include looking for emergence and trying to approximate germination rate. It may be difficult to determine

emergence of seedlings until floral development eases identification later in the season. If *B. carinatus* reaches higher than desired densities, some clearing and supplemental seeding of other target species may be needed in following years. However, high densities may be beneficial for excluding undesirable invasive species. Higher densities of *B. carinatus* could be planted in edge and roadside areas that are particularly prone to invasion (though not those edges that are adjacent to agriculture). Once a desired density is reached, longer term monitoring should look for spread into nearby agricultural areas or spread into restoration site areas that abut agricultural lands. Monitoring of these areas can occur on a yearly basis when floral spike development of established seedlings permits positive identification. Additionally, small mammal populations should be monitored and promoted as a control on recruitment of *B. carinatus* from naturally dispersed seed.

The potential problem of most concern for *B. carinatus* restoration is that it could competitively exclude other target species being utilized at the restoration site. Planting *B. carinatus* in moderate to high densities represents a restoration risk. This risk can be minimized by using low seeding densities or planting in discrete patches. This restoration plan could help to address some questions concerning these two alternative planting schemes (low density mixes vs. monotypic patches for competitive species). For example, do these two methods lead to the same resulting community structure over time? Are the two methods comparable in achieving initial establishment success, and if so what part does seeding rate play in this? A simple experimental design incorporated into the restoration plan could help to address these questions.

Part III

The general goal of this restoration project is to restore the site to a plant community representative of pre-degradation conditions. The suite of species selected for community assembly will be chosen based on the current physical and chemical conditions of the site, our predictions of ecological interactions that could occur given a particular community assemblage, and the composition of nearby intact or historically-based 'reference sites.' By choosing community members based on current physical and chemical conditions, we will increase the likelihood of survival for given populations. Only those species that are tolerant of current site conditions or of the conditions that we can impose (e.g. with seedling tubes, soil amendments, etc.) will be used for initial planting. In some cases, however, planting of one species will facilitate the establishment of others. Alternatively, even if a given species is tolerant of preexisting conditions, biotic interactions with other planted species could inhibit its establishment. Predictions of these sorts of ecological interactions will aid in species selection. Perhaps our most important and useful tool for community assembly will be use of reference sites. By observing what species coexist on similar sites nearby, we can attempt to mimic the natural processes that have already proven successful. If the reference site utilized is close in proximity to the restoration site, then we can also predict some additional aid in establishment from natural propagule availability.

B. carinatus can be utilized on the site for three main purposes: 1) as part of a native, natural community assemblage, with all of the functions associated with that role (such as food and habitat provision for wildlife); 2) as a soil stabilizer in erosion-prone areas; and 3) as a competitive species capable of excluding exotic invasive species. The seeds and foliage of California brome can help to support populations of small rodents and some bird species, which in turn will help to support populations of higher trophic level organisms. Though it is capable of establishment and survival under a broad range of conditions, *B. carinatus* is most appropriate for planting in and around the drier basins that more closely approximate ‘upland’ conditions. Its third purpose can at times be at odds with the goal of establishing less competitive native species. However, this potential problem could be avoided either by spatial separation of plantings or by using a low density of *B. carinatus* seeds when planted in a native mixture. In addition, this purpose can be put to good use in invasion-prone sections of the restoration site, as a preemptive measure for resisting invasive establishment.

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Creeping Wildrye Restoration

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Part 1

My portion of the project focuses on the benefits of utilizing *Leymus triticoides* in restoration projects. *Leymus triticoides*, common names including creeping wildrye, beardless wildrye, and alkali wildrye, is a meadow grass that typically grows 3' tall and spreads through rhizomes (a horizontal-growing stem underground that sends out roots and shoots from a node). Creeping wildrye grows on heavy, or high clay content, soils in riparian areas, valleys, foothills, mountain flats, and meadows from coastal marshes to higher elevations.

Creeping wildrye restoration is important because of its former dominance in the Central Valley landscape. According to Glen Holstein "*Leymus triticoides* formerly dominated much of the Central Valley," but in the present-day Central Valley, "prairie remnants…dominated by *Leymus triticoides*…are still extant in central California" and "are particularly frequent in Sacramento County" (Holstein, 2001). Prior to the conversion of many native grasslands, oak woodlands, and riparian forests into agricultural fields, and the introduction of exotic annual grasses, creeping wildrye was a dominant species due to its persistence and rhizomatous growth habit. This is evidenced by the writings of noted California explorers John Fremont and Edwin Bryant. In 1845 while camped at a site near present-day Sacramento, Fremont wrote that "here the grass is smooth and green, and the groves very open: the large oaks throwing a broad shade among sunny spots" (Holstein, 2001). Holstein supposes this account refers to creeping wildrye due to the "smooth aspect" and the many "relict stands near Sacramento"

(Holstein, 2001). One year later on September 14 near present-day Livermore, Bryant wrote “We crossed the Coscumne River about a mile from our camp, and traveled over a level plain covered with luxuriant grass and timbered with evergreen oak” (Holstein, 2001). Holstein also assumes Bryant refers to creeping wildrye because it “is the only common native or non-native Central Valley grass associated with oaks which would be ‘luxuriant’ in September before irrigation was widely introduced” (Holstein, 2001).

There are two cultivars of creeping wildrye pertinent to Central Valley, CA restoration projects: ‘Rio’ and ‘Yolo’. Both cultivars are well-suited to the Central Valley’s Mediterranean climate and have superior seed viability. Existing natural populations, on the other hand, are considered largely sterile (Holstein, 2001). Despite this, creeping wildrye is often still dominant due to its rhizomatous growth. Creeping wildrye resists trampling, recovers well from grazing, and is fire-tolerant (USDA NRCS, 2009). Creeping wildrye is useful for erosion control because it forms mats of grass and holds heavy soils together through a dense root system that can extend from 10” to 10’ into soil. It is also saline-tolerant and can tolerate a pH ranging from 6-9(USDA NRCS, 2009). Once established it can spread rapidly and form large colonies.

Creeping wildrye also has low invasibility, as evidenced by a study which found that in plots of creeping wildrye, biomass of non-native grasses was 90% less than that of the control plot (Lulow, 2006). Lulow observed that species which spread through rhizomes, like creeping wildrye, “may have an advantage over tufted species in resisting invasion by annual grasses because they fill more space in the shallow soil layers" (Lulow, 2006).

There are a number of challenges to restoration of creeping wildrye:

- Creeping wildrye has high biomass above and below-ground, meaning that it can outcompete exotic annual grasses, as well as other native grasses and forbs, for both light and soil
- Rarity of viable seed (studies by Stebbins and Walters concluded that the grass traditionally called *Leymus triticoides* in natural populations is a largely sterile hybrid between *L. triticoides* and *L. condensatus*) (Holstein, 2001). This is expected to only affect germation and establishment, as creeping wildrye will spread rapidly through underground rhizomes once established.
- Grows better and yields more when the soil is moist (0.3 bar) rather than dry (10 bar) or saturated (0 bar) (some discrepancy found in the research on this subject as the PLANTS database lists creeping wildrye as highly drought-tolerant while Jeanne C. Chambers and Amy R. Linnerooth found that the highest life-span estimates for creeping wildrye were on wet and intermediate sites, rather than the dry sites) (Chambers and Linnerooth, 2001)
- Less adapted to coarse-textured soils
- Low invasibility, representing how creeping wildrye can act as a negative feedback for the invasion of exotic grasses
- Application of Nitrogen fertilizer is ineffective due to small production response, "especially when large amounts of N are applied" (Gomm, 1978)

- Germination relatively unaffected by the presence of salts
- Key gaps in the knowledge about creeping wildrye include the preferred method of establishment at a site (seeding, plugs, etc.) as well as its ecological benefits to various native fauna

There are a number of restoration and management techniques that have been proven effective, as well as a number of uncertainties:

- Prechilling of seed at 1.5 degrees Celsius for 5 days; this will increase imbibation (uptake of water by seed) (Wagner and Chapman, 1970)
- Preparation of site including discing twice prior to planting, once in spring and once in winter and the application of broad-spectrum herbicide two weeks before planting (Lulow, 2006)
- Mowing in late spring of the first year prior to planting before the ripening of non-native annual grass seed to reduce annual grass recruitment (Lulow, 2006)
- Application of broadleaf herbicide once per year in spring for first three years (Lulow, 2006)
- Low intensity burning in fifth year following initial fall rains to reduce thatch and increase light reaching growth meristems (Lulow, 2006)
- Uncertain on whether creeping wildrye performs better on wet or dry sites found in the research. Studies by Chambers and Linnerooth, as well as Gomm, concluded that creeping wildrye performs best on wet sites, followed by intermediate and then dry, while the PLANTS database lists creeping wildrye as

highly drought-tolerant (Gomm, 1978; PLANTS database, 2009; Chambers and Linnerooth, 2001).

- Unsure of preferred method of establishment, seeds or plugs, as research yielded studies that found success with both applications, but no study that compared the two methods

Part 2

Creeping wildrye (*Leymus triticoides*) is a perennial grass that was dominant throughout the Central Valley prior to the introduction of agriculture and housing developments, as well as the introduction of exotic annuals in the early 1800's. Its rhizomatous growth habit means it spreads rapidly and forms dense colonies, but its large biomass above and below-ground can not only outcompete exotic annuals, but also other native grasses and forbs. I believe there are two goals for the restoration of creeping wildrye:

- Goal 1: Establish small patches of creeping wildrye, which will outcompete exotic annuals in the patches but will also allow other native grasses and forbs enough soil space and light to become established; this will allow for higher plant diversity, resulting in increased biodiversity
  - Spatial Scale: Small (approximately 5-10 square feet) patches should be established throughout the site, preferably bordering patches of other highly competitive grasses like California brome (*Bromus carinatus*) to reduce likelihood of outcompeting more sensitive native grasses and forbs; these small patches will inevitably expand outward, but hopefully not before other grasses and forbs have a chance to get established
  - Temporal Scale: Creeping wildrye should be planted in small patches following site management (discing and application of broad-spectrum herbicide to reduce exotic annual invasion) and managed (mowing and/or grazing and the application of broadleaf herbicide) for at least a year before the introduction of native forbs to reduce the presence of exotics and ensure a higher likelihood of forb establishment in the space

not occupied by creeping wildrye; over time the small patches of creeping wildrye will expand and will require more management, including burning, mowing, and grazing to reduce thatch, which would reduce light competition and likelihood of fire

- Tradeoff: By only planting creeping wildrye in small patches, we risk a higher likelihood of invasion by exotic annuals in return for the possibility of higher plant diversity
- Feedback: Possible positive feedback in relation to exotic annual populations, which, if allowed to establish, will continue to grow
- Interactions: There is a possibility that creeping wildrye will dominate, but by creating small patches and following the management plan the hope is that exotic annual invasion can be reduced while encouraging the establishment of other native grasses and forbs in the open spaces around creeping wildrye, allowing for increased biodiversity
- Threshold:

  See Paper Copy for Resilience Diagram

  For Goal 1, likelihood of invasion is higher and it is easier for exotics to invade. Once exotics become established, it will be more difficult to transfer from a high invasion state to a lower one.

- Goal 2: Establish large, dense stands of creeping wildrye in order to keep out exotic annuals, even at the expense of other native grasses and forbs
  - Spatial Scale: Creeping wildrye should be planted all throughout the site, particularly in the wetter basins, to increase the likelihood of establishment and creation of dense stands, which will outcompete exotic annuals for both light and soil space

- Temporal Scale: Creeping wildrye should be planted following site management (discing and application of broad-spectrum herbicide to reduce exotic annual invasion) and managed (mowing and/or grazing and the application of broadleaf herbicide) for at least three years before the introduction of native forbs; this will allow for the establishment and spread of creeping wildrye on sites that it is most suited to and, after the first three years, the forbs will be able to become established with less competition from exotic annuals in the spaces not already occupied by creeping wildrye; management of creeping wildrye will need to continue with mowing and/or grazing in the late spring to reduce annual grass recruitment as well as prescribed burns every five years to reduce thatch and fuel
- Tradeoff: Lower likelihood of invasion by exotic annuals for decreased plant diversity and biodiversity
- Feedback: Possible negative feedback for exotic annuals via low invasibility; possible positive feedback for the dominance of creeping wildrye: as creeping wildrye establishes and spreads, it may continuously outcompete other natives
- Interactions: Creeping wildrye will likely outcompete other native grasses and forbs, reducing biodiversity
- Threshold:

  See Paper Copy for Resilience Diagram

  For Goal 2, likelihood of invasion is lower and, once in a low invasion state, it is more difficult for exotics to invade. Also, should exotics invade it will be easier to move from a high invasion state to a lower one.

<u>Recommended Restoration Plan</u>

For site preparation, the site should be disced twice prior to planting, once in spring and once in winter, and broadleaf herbicide should be applied two weeks prior to planting. Direct seeding is recommended as it is less expensive and there is inadequate research on whether seeding or transplanting of plugs is more effective. The 'Yolo' cultivar is recommended for seeding due to superior seed viability, lower likelihood of seed shatter, and it is well-suited to the Central Valley's Mediterranean climate.

- **Goal 1**
  - 5-10 square foot patches should be seeded in high density
  - Should establishment of small populations fail I recommend seeding over a larger area and/or transplanting plugs
  - Should creeping wildrye expand quickly outside of the patches and begin to dominate, increased management via grazing, mowing, and burning is recommended to decrease light competition. This could be done at any time in the season as a large amount of creeping wildrye's biomass is in its dense root system and because it spreads through belowground rhizomes rather than seeds.
  - Risk with the plan for Goal 1 is that, despite limiting seeding to small patches, creeping wildrye may still dominate and outcompete other natives for light and soil
  - Monitoring of Goal 1 should be done by setting up a transect in the basins containing stands of creeping wildrye, once in the spring and once in the winter of each year. This transect would be used to measure the presence of exotic annuals (inside or outside the stands), the rate at which the stands grow outward, whether or not other vegetation is established within the stands, and what vegetation is established outside of the stands.

- **Goal 2**
  - Seeds should be broadcast throughout the site in moderate density
  - Should only small patches become established I recommend adoption of Goal 1 and increased application of broadleaf herbicides in spring and mowing in late spring to keep exotic annual populations down
  - Risk with the plan for Goal 2 is that, with a creeping wildrye dominated site, there will be lower plant diversity and, in turn, lower biodiversity
  - Monitoring of Goal 2 should consist of setting up transects within each basin that contains creeping wildrye. The transects can then be used to determine how widespread creeping wildrye is within the basin, generally how dominant it is, and whether or not there are exotic annuals present.

For both goals it is uncertain whether direct seeding will result in viable communities, as well as how creeping wildrye will perform in the varied soil conditions (moisture content, fertility, infiltration).

In order to improve both plans, there are two important research questions that need to be answered: Does seeding or transplanting plugs have higher establishment rates? There are currently no studies that compare the germination and establishment rates of direct seeding to transplanting. Direct seeding is generally less expensive than transplanting, but it could exclude locally adapted genotypes. The other question is how big of a factor soil moisture is in the germination, establishment, and life span of creeping wildrye? The PLANTS database lists creeping wildrye as highly drought-tolerant. On the other hand, a study by Chambers and Linnerooth suggests that creeping wildrye is found to have the highest life span rates on intermediate and wet sites, and Gomm found that the highest establishment rates were on intermediate and wet sites. Both of these questions could be answered in this restoration project if plots of creeping wildrye were both seeded and transplanted with plugs in areas with known moisture conditions of wet, intermediate, and dry.

Part III

In order to account for all other goals, I recommend implementing Goal 1 for creeping wildrye restoration. Goal 1 provides the highest probability of achieving plant diversity, which will also support a more diverse range of native wildlife. By outcompeting exotic annuals for light and soil, creeping wildrye can prevent reinvasion following site management. However, the propensity for creeping wildrye to dominate can lead to out-competition of other native grasses and forbs, lowering plant diversity. By planting creeping wildrye in only small stands bordered by California brome (*Bromus carinatus*), another highly competitive native grass, creeping wildrye should not dominate the site and should allow for establishment of grasses and forbs in the open spaces. This will allow for higher diversity within the site and will support a more diverse wildlife population. For example, creeping wildrye supports higher populations of voles, which will in turn support white-tailed kite (*Elanus leucurus*).

The tradeoffs associated with the restoration of creeping wildrye are reinvasion, creeping wildrye dominance, and establishment of other native grasses and forbs. As creeping wildrye becomes more dominant, the chances of reinvasion are reduced but so is the establishment of other native grasses and forbs. When creeping wildrye is not dominant there is a much higher likelihood of the establishment of native grasses and forbs, but there is also a much higher likelihood that exotic annuals will reinvade the site and still push out native grasses and forbs.

Ponds

Terracing the landfill into upland, wetland, and mesic areas can be beneficial to creeping wildrye because it will show on a small scale how creeping wildrye interacts with other native grasses (Will it dominate? What can compete with it? What will it outcompete?).

Riparian/Stream

Restoring the riparian corridor can have a negative impact on creeping wildrye as it will need to be monitored and managed extensively to ensure that it does not dominate and/or shade out blue elderberry, willow, and/or valley oak seedlings. A positive impact on creeping wildrye will be to see how it reacts to varying moisture conditions along the corridor.

Upland Areas

The upland areas scenario will provide a positive impact on creeping wildrye by providing varying conditions to test it, as well as to allow for creeping wildrye to form small, dense patches and prevent reinvasion of exotic annuals in those patches. Also, creeping wildrye can tolerate a wide range of heavy disturbance (burning, mowing, heavy grazing), allowing for easier establishment of forbs later on into restoration.

I think that the best case scenario for the restoration of creeping wildrye is the upland areas scenario as it will allow creeping wildrye to form small, dense patches in varying conditions and outcompete exotic annuals in the patches while providing a chance for other natives to become established in the open, disturbed spaces. I think that the worst case scenario for creeping wildrye is the riparian/stream scenario as it will call for extensive monitoring and management to keep creeping wildrye from shading out riparian seedlings. Also, in the riparian corridor it will be less used as cover for voles (prefer large, open expanses of native grass), the main forage for white-tailed kite.

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Restoration of *Vulpia Microstachys*, or Small Fescue
By Kimberly Yeo

PART I: PROJECT BACKGROUND AND JUSTIFICATION

This quarter, our restoration ecology class has taken on the task of finding methods to restore the site around the Davis aquaculture facility west of the University of California, Davis campus. The site is isolated from developed areas of the city and is surrounded by agricultural fields, open space, the UC Primate Research Center and the Putah Creek channel to its south. Approximately 60 acres large, our goal is to rejuvenate the existing ecosystem so that animals and plants can utilize the space for resources and habitat. My task will focus on researching the affects, beneficial or detrimental, of growing *Vulpia microstachys* on the site.

LOCATION & BOTANICAL CHARACTERISTICS

*Vulpia microsta*chys has several common names such as small, desert or six-weeks fescue. It is an annual native grass that is most commonly found in the western portions of North America. It can be spotted in states west of Montana and down to New Mexico. Outside of the United States, researchers have also found populations of *Vulpia microstachys* in southern British Columbia, the pacific slopes of South America and along Baja California (USDA Forest Service, 2009). Small fescue is an unusual species because it thrives on serpentine soils. These soils usually lack the presence of essential nutrients such as nitrogen, phosphorus and potassium which often help other plants grow. *Vulpia microstachys* is found in California valley and foothill communities such as the yellow pine forest, foothill woodland, chaparral and valley grasslands (CalFlora, 2009).

Small fescue can grow from 15-75cm long (6-30 inches) in solitary or small tufts. This grass can be identified by its many flowered panicle and by its seed, a caryopsis (USDA Forest Service, 2009). Seed dispersal is usually carried out by the wind, but in some instances, animals can scatter seeds around the area.

BENEFITS

The presence of *Vulpia microstachys* on site provides several benefits such as erosion control, habitat for wildlife and serves as a food source. Above ground, the vegetation helps lessen water impact onto the soil. Below ground, the fibrous root systems help keep the soil intact by creating a support matrix. Small fescue provides the ecosystem with resources and habitat for small mammals and insects. Managed fields offer nesting sites, protective cover and insect populations for food. The grass also acts as a traffic corridor for animals and birds. (NRCS, 2007). Small fescue allows for other perennial grasses to establish while it grows in the area. Unlike exotics, which often invade and take over an ecosystem, *Vulpia microstachys* is a mutually coexistent species which can grow with other plants (Schalau, 2009).

Table 1
*Below is the list from the California Native Plant Exchange of plants that grow well with *Vulpia microstachys*.
Highlighted species are other plants that will be discussed in the restoration plan.

Achillea millefolium	Common Yarrow
Elymus glaucus	Blue Wildrye
Sambucus Mexicana	**Blue Elderberry**
Mimulus Parishii	Parish Mimulus
Eschscholzia californica	**California Poppy**
Schoenoplectus Acutus	Hardstem Bulrush
Bromus Carinatus	**California Bromegrass**

Lastly, it serves as a palatable food source for cattle, horses and domestic sheep. Cattle and horses find small fescue appetizing, but sheep will graze on it if there is no other edible vegetation available (USDA Forest Service, 2009).

CURRENT POPULATIONS

Currently, not much is known about the state of *Vulpia microstachys* populations. However, we do know that populations of native grasses are in decline. According to an article written by Richard Reiner, "Nearly all of the grasslands in our Central Valley were lost to cultivation near the turn of the century, and as of 1987 only 1% of the valley grassland remained" (Reiner, 2007). Factors such as urbanization, land cultivation and invasion of exotic species are major contributors to the decline in native grasslands. Introduced annual grasses now dominate much of the grassland habitats. Populations of exotics began spreading when they were introduced by Europeans during the 1800s.

FUNDING

Restoring native grasslands has become a very important issue for many environmental groups. Although there is not specific funding for *Vulpia microstachys* restoration, it can possibly be integrated with management plans for native grassland restoration. Groups such as the Society for Ecological Restoration, California (SERCAL) and the California Native Plant Society (CNPS) are working to restore ecosystems that are degraded. Their work is primarily done through restoration projects, conferences, public meetings and school outreach with fieldtrips to restoration sites.

LITERATURE REVIEW

For any restoration project, it is essential to know what factors can positively or negatively affect species success in the ecosystem. Analyzing the biotic and abiotic factors that affect the species will determine if and how the species will be used on that particular site. Plants and animals are not the only interactions that we must consider. Determining what levels of human assistance are needed to restore the site is another consideration.

ABIOTIC FACTORS

In the 1982 study conducted by Turitzin in the Jasper Ridge Biological Reserve, he researched the affects of nutrient limitations on plant growth. Tests were conducted in the field and in controlled pot settings. Besides *Vulpia microstachys*, researchers also tested the affects of nutrient limitations to *Bromus mollis*. This particular study noted that "nitrogen and phosphorus were identified as nutrients limiting the growth of plants in an herbaceous community on serpentine soils" (Turitzin, 1982). When potassium, sulfur and calcium were amended into the soil, little to no effect was noted in plant response. These results differ from studies conducted two decades later. In the 2002 study conducted by Jurjavcic, Harrison and Wolf, the group tried to measure the affect of abiotic stress factors on the growth rate of *Vulpia microstachys*. The study was done at the Donald and Sylvia McLaughlin University of California Reserve in Napa County. Three distinct ecosystems are interwoven on site which includes: non-serpentine grasslands, serpentine meadows and rocky serpentine slopes. Measuring the growth above ground, with plant biomass and height, and below ground, with root biomass, researchers were able to determine which conditions contribute to the growth of small fescue. "In pot experiments, growth responded positively to nutrient (Nitrogen and Phosphorus) addition” (Jurjavcic, 2002). Although in this particular study, nitrogen and phosphorus proved to be beneficial to *V. microstachys,* it also increased the growth rate of a competing tall invasive on site, *Avena fatua*.

Soil crust composition determines the amount of seed water potential and germination rate. Serpe performed a study on the species *Bromus tectorum* and *Vulpia microstachys* in three different environments. Tests were done on bare soil, crusts with various lichens and mosses (mixed crust) and crusts dominated by the crustose lichen (Diploschtes crust). Results showed that small fescue did better with germination and water potential in the mixed soil compared to the bare soil. And both *Bromus tectorum* and *Vulpia microstachys* have greater water holding properties in the bare and mixed crust soils compared to the Diploschites crust soil. “Our results indicate that the presence of *D. muscorum* can inhibit seedling establishment by 2 mechanisms: a reduction in water absorption and an increase in root tip mortality” (Serpe, 2007). The crustose lichen causes the root tips to become infected and decay. This leads to a decline in populations of *Bromus tectorum* and *Vulpia microstachys*.

BIOLOGIC FACTORS

Several biologic factors can affect species’ growth rates and abundance. Studies on the behaviors of pocket gophers have been tested to determine the amount of disturbance they cause to soils. In a 1985 study done by Hobbs and Mooney, they looked at the effects of soil disturbance by pocket gophers on various grass species. Data was collected measuring production, dispersal, storage of seed, germination, survivorship and growth in disturbed and undisturbed areas. Taller grasses seemed to be preferred by the pocket gophers, offering them more habitat cover. The presence of gopher activity was noted to have both positive and negative effects. Gophers can be troublesome to already existent populations of *Vulpia microstachys* because they can disturb grass rooting systems. In areas where there are no populations present, gopher tillage can help promote the establishment of mycorrhizal networks (Ritter, 2006). Hobbs and Mooney observed that the numbers of *Vulpia microstachys* declined from undisturbed areas to gopher mounds. They noted that above ground biomass, number of plants and seedlings germinated all decreased when the area was populated with gophers (Hobbs and Mooney, 1985). Populations also were dependent on the time of year. More research on gopher disturbance needs to be done to confirm results.

Black harvester ants also influence plant community composition. "Seed-harvesting ants such as *M. andrei* can influence plant community composition through both the selective harvesting of seeds and the construction of nutrient-rich nest mounds…" (Halton, 2005). Mounds created by the black harvester ants often contain high levels of phosphorus and nitrogen. Tested on areas in the Jasper Ridge Biological Preserve in San Mateo County, *Vulpia microstachys* was less commonly seen on nest mounds. This could possibly clarify the previous study done by Jurjavcic, that small fescue does not prefer NPK amendments to the soil.

MANAGEMENT

There are two methods of management that have been studied by ecologists. Fire and grazing are two options to consider when restoring a site. *Vulpia microstachys* is fairly tolerable of fire. A study was conducted in late September of 1994 after a lightning fire burned a site. Data was taken on the re-growth of small fescue on burned and unburned areas. *Vulpia microstachys* had the highest relative density of growth in both burned and unburned plots. Seedlings in the ground are able to survive surface fires. However, if the fire's heat penetrates the soil too intensely, *Vulpia microstachys* seedlings will die. According to the USDA Forest Service, small fescue seedlings were reported dead after 1 hour of burning at 115- 121 Degrees Fahrenheit in moist soil conditions (USDA Forest Service, 2009). Early summer burns would allow for growth to continue at the root tips. "One season of results indicate that burning in the summer or fall may reduce non-native species … and increase native-species diversity on McKenzie Table" (York, 1997). However, if populations of bromes, schismus and or lovegrasses are present before the fire or are represented in the seed bank, the post-fire population is likely to be reduced.

Grazing is the other option that restoration managers can choose to implement on the site. The USDA Forest Service states that moderate to heavy grazing can help populations of *Vulpia Microstachys*. Cattle and horses prefer to graze on it compared to domestic sheep. Sheep will eat small fescue if there is no other edible vegetation around. Grazing should be done in the early spring.

UNCERTAINTIES

More information needs to be gathered in order for us to know more about *Vulpia microstachys* and their interactions with other plants and animals. Although we know that small fescue is a relatively fast growing grass, we are still unsure of its growth rates each year. And as stated in this report, conflicting studies on effects of both NPK amendments and gopher disturbance on *Vulpia microstachys* need to be researched more thoroughly in the future. Studies on fire and grazing have been conducted, but not much research has been done on the effects of mowing. Learning about *Vulpia microstachys'* regeneration requirements would better prepare us to come up with a more successful management plan for the site.

PART II: GOALS AND MANAGEMENT PLANS

Some of the goals we have set for populations of *Vulpia microstachys* are to: decrease invasives, increase populations of *Vulpia microstachys* and prevent reinvasion from occurring on site.

DECREASE INVASIVES

Depending on the history and existing conditions of the site, reducing the amount of invasive and exotic species can be done in several ways. If the site is small or weeds are dispersed in an area where native plants are also present, hand weeding can be done to eliminate unwanted vegetation. This process can be slow, but is effective if plants are removed before seeding. "Hand-weeding must be repeated frequently until the plantings become established" (Wilen, 2007). Larger sites can use controlled fire burns to eliminate certain patches of exotics. Setting up smaller burn sites help fire personnel control the behavior and route of the burn. It is important to remove invasives in the burn area before fires are set. "A postfire reduction in sixweeks grass is likely if annual bromes, schismus, and/or lovegrasses are present before fire or represented in the seed bank" (USDA Forest

Service). Although fire is effective in clearing out vegetation, using it as a management tool has drawbacks such as safety and health concerns for plants, animals and humans.

INCREASE POPULATIONS OF *VULPIA MICROSTACHYS*

Populations of small fescue are found in communities such as the yellow pine forest, foothill woodland, chaparral, and valley grasslands. They are acclimated to landscapes with dry messic soils and prefer to grow on serpentine soils (USDA Forest Service, 2009). Small fescue thrives on soils which lack nutrients. It's ability to do well in serpentine soils give it an advantage over some exotics, which do not prefer these soils. It would be beneficial to plant *Vulpia microstachys* where problems of erosion might occur for the reason that it is a good stabilizing agent. It also allows for other native species of grasses and forbs to grow in the site (Schalau, 2009). Germination of seedlings approximately begins at the onset of fall precipitation.

PREVENTION OF REINVASION

Make sure to have a well established cover of *Vulpia microstachys* on site. This can be accomplished by hand weeding any unwanted plants that arise during the growing season (Wilen, 2007). The presence of small fescue will reduce the chances of invasive or exotics inhabiting the area. Grazing in fall will help rejuvenate root tips for replenished growth. After grazing is done, be sure to monitor the site with periodic weekly visits. Grazing can open the vegetative canopy and lead to increased chances of competition with some exotics (USDA Forest Service).

RESTORATION

1. **Site preparation**- Clear the site using of herbicide and controlled fire burns in the areas where exotics are present. Disking the previous groundcover will help aerate compacted soils. Next, irrigate the project area to provide enough moisture for *Vulpia microstachys* seedlings to germinate. Supplemental irrigation may be required during very dry months.
2. **Planting**- *Vulpia microstachys* can only regenerate from seeds. Small fescue should be planted at approximately 50 seeds per square foot. If there are drier serpentine soils on site, seedlings should be planted in these areas because they show higher growth rates. NPK amendments or calcium supplements can be added to the soil to test whether or not it will increase growth rates and abundance (USDA Forest Service). A 10 meter square test plot should be allocated on site to conduct the experiment. (Previous studies show inconsistent results where NPK amendments to the soil actually inhibit plant growth.) The top layer of the ground should be covered with 0.3-0.5 inches of topsoil to moderate temperature and protect the seeds. If this cannot be done imprinting or drilling are other options. Imprinting involves shaping the soil, creating small depressions which concentrate water, seed, litter, and other resources. Drilling uses a specialized machine to dig to a certain depth and place seeds into the hole. The machine then covers the seed with soil (Ritter, 2006). Ritter notes in his study concerning the effectiveness of the two methods, native plants were better introduced to the site by imprinting compared to drilling. Germination occurs in mid October and the flowering period lasts from March to June in California.

3. **Exotic Control-** Hand weeding or spraying herbicides can be done to remove areas of invasive species as discussed previously.
4. **Longevity**- Regular monitoring of species recommended for the first 3 years. This can be done by recording the percentage of exotic plants in test quadrants to determine the rate of invasion. If exotics begin to grow on the site, they should be removed to reduce mass invasion of unwanted species. Grazing can be done every other year to rejuvenate *Vulpia microstachys* root tips and promote growth.

PART III: REVISED PLAN AND GOALS

According to Table 1, restoring populations of *Vulpia microstachys* will also benefit restoration plans for blue elderberry (*Sambucus Mexicana)* and California brome (*Hordeum brachyantherum*) populations in our particular site.

Blue Elderberry is a native plant that serves many functions in the community. The berries are a valued food source for birds and animals, and the shrub is habitat for the endangered longhorn elderberry beetle. Although restoring *Sambucus mexicana* has benefits, if the shrub grows too large, a problem might occur where it starts shading out the low growing *Vulpia microstachys*. If there are many elderberry shrubs, water intake will also be diminished for *Vulpia.*

California Brome, a rangeland forage grass, provides habitat for many animals and can be used as an erosion control agent. It too is a native grass and is considered a very good competitor to exotics. Its low invasibility protects exotics from entering the site; however its competitiveness also weakens the chances of success for *Vulpia microstachys*. California brome does not fare well with grazing because the high intensity trampling destroys seed viability. The grass has moderate resistance to mowing.

REVISED PLAN

Considering the restoration plans for blue elderberry and California brome, we will want to consider planting *Vulpia microstachys* on site first, allowing them to get established. Because California brome is an especially dominant species, we want *Vulpia microstachys* to grow earlier to give it a better chance of competing with other grasses, forbs and woody shrubs. Looking at the project site, Basin 3 and Basin 5 seem like better options for planting. Levels of nitrogen, phosphorus and potassium at the site range from low to moderate; which are preferable for *Vulpia*, *Sambucus* and *Hordeum*. *Vulpia microstachys* populations already exist in Basin 3 and data has been collected showing that blue elderberry in present in Basin 5. Plantings of small fescue, blue elderberry and California brome should be intermixed. This would not encourage dominance of one species and give the smaller growing fescue better success at the site. Because blue elderberry and California brome do not like heavy grazing, sheep can be used on site. Each species' grazing period varies, so testing for the first few years will need to be done to determine the best season for all species.

GOAL SUMMARIES

One of our class goals was to restore populations of native grasses on site. To achieve this goal, we had to focus our efforts in creating a substantial population of grasses, before looking into species restoration of forbs and woody shrubs. Utilizing the land for native grasses could consequently mean that forbs would not get much land to grow.

Our next class goal was to create a larger riparian community along the southern edge and pond areas of the site. Extending the riparian corridor would produce habitat for birds and animals like the swainson hawk, giant garter snake and he western pond turtle.

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Native forb species

Caitlin Talkington

Restoration of *Asclepias fascicularis*

Part I.

The goal of this project is to introduce native forb species *Asclepias fascicularis,* the Narrow leaf milkweed, into the Putah Creek Reserve as a means of enhancing habitat for wildlife, encouraging the aesthetic and cultural values of native plants and to increase protection from invasion of exotic species. In general, competition from exotic and invasive species has limited the distribution of native forb species. Improper land use and urbanization has fragmented populations of native forb species (Carlsen 2000). Wildlife habitat, especially for pollinators, diminishes as well as a result of these destructive practices. It is important to value restoring native plants to our ecosystems for the aesthetic and cultural benefits they provide us. The beauty of native landscapes can be seen in the balance and variety of life forms in a given ecosystem. This can be easily lost when domineering exotic species overrun communities. Although restoration efforts for native grasses and tree species like oaks have been ongoing, introducing native forbs to communities has been a more recent and complex endeavor (Brown 2001).

Asclepias fascicularis, is a dicotyledon, perennial herb in the Asclepiadaceae family. It is a summer growing rhizomatous species that emerges in the spring time, blooms in the summer months, and dies back in the fall. At the peak of its growing season it can reach up to 120-150 cm (4 to 5 ft.). It has narrow lanceloate leaves that appear in whorls of 3-5 around the stem (USDA). The flowers are greenish white, sometimes with a purple tint and appear in dense clusters (Las Pilitas Nursery). All plants of the genera *Asclepias* have unique flowers made up of reflexed corollas with a showy hood-like appendage called a corona that is attached above it. The showy flowers also have nectar glands and armed pollinia that attach to the pollinators they attract. The foliage of this plant also produces a milky latex sap which has toxic alkaloids. Coming in contact with the sap can cause minor dermatitis, a condition which results in skin irritation or a rash that may persist for a short period of time (USDA). Most *Asclepias* are self-sterile, but not entirely self-incompatible, meaning the ovules can be fertilized, but will be rejected as zygotes (Lipow 2000). The fruits are erect pedicels that harden and open to release small < 1cm long seeds with around 3 cm. long white comas of silky hairs (Jepson Interchange and Calflora). The seeds are wind dispersed, but *A. fascicularis* also spreads clonally through its underground rhizomes (USDA).

A. fascicularis is native to California and other western states with a distribution primarily limited to the western United States, Canada, and upper regions of Mexico (USDA). It has been found growing in a variety of habitats such as oak woodlands, mixed evergreen forests, chaparral, grasslands, wetlands and riparian areas. It tolerates dry to moist soils, and can effectively colonize a large range of habitat types (Robson 2008 and Brown 2001). The narrow leaf milkweed is found equally in wetland and non wetlands regions (FWS). Sightings of this species have occurred in Yolo and other surrounding counties in the central valley (Calflora). The Putah Creek Reserve site has possible riparian basin and uplands areas, all of which may be suitable for introductions of the *A. fascicularis*.

It is important to consider the wildlife species that will benefit from the introduction of *A. fascicularis.* A broad spectrum of pollinators and aphidophagous insects can use *Asclepias spp.* for nectar (Brown 2001). Large milkweed bug, common milkweed bug, red milkweed beetle, blue milkweed beetle and bees also use milkweeds as a food source (USDA). One species which has evolved a special relationship with the milkweed is the Monarch butterfly, *Danaus plexippus.* Although monarch populations are not near extinction, their migration ecology is labeled “endangered biological phenomenon” by the IUCN. This means that the migration process of the butterfly and associated habitats are being lost, which puts future monarch populations at risk. This migration is necessary for finding mates and a loss of habitat inevitably harms future populations of monarchs. Milkweeds are the primary food source of the Monarch and are the only plants used by butterflies for their entire life cycle. They lay their eggs, the larvae feed on the plant tissues, and mature stages form a chrysalis. Several factors determine their preference for certain species over others, including mature plant size, age and cardenolide concentration levels in the sap and tissues of *Asclepias spp.* (Ladner 2005). This is because the alkaloids associated with the plant sap provide protection for Monarchs from predators (USDA). The Monarchs consume the plant tissues as larvae and sequester these cardenolides, rendering them toxic to predators. Monarchs have evolved with specific native species in their territories to provide them with the highest benefit of protection and in turn the milkweeds are insured pollinators. Choosing an *Asclepias* species from an exotic region not naturally associated with the Monarch can be harmful to the species in that the compounds may actually slow instar larvae growth or decrease likelihood of survival (Ladner 2005). Ladner’s study of oviposition preference and larval performance with various *Asclepias spp.* found that larvae originating from the west coast had the highest survival and growth rates when hosting on *A. fascicularis.*

The cultural heritage of milkweeds is also of consideration as ethnobotanical uses were very vast. The Native Americans of the Mendocino County, the Yokia Indians, ate raw *Asclepias fascicularis* flower blossoms and used the heated sap to make a chewing gum. Pueblo people also included the green seed pods and underground tubers in their diet. The fibers have been used for textiles and certain components of sap used medicinally in the US and Canada (USDA).

Tilman's study (1997) of plant communities suggests that when many types of native plant species are added to grasslands, such as forbs, species richness and abundance increased. Diverse communities are also noted as being better able to recover from drought in many situations, but this depends on the species that make up the community. Considering climate change it may be of added benefit to work towards restoring sites with a more diverse set of species. In Brown's establishment of native forb species amongst perennial grasses, weed canopy cover was lowered with the introduction of the flowering species. The decrease in weeds was only seen when a mix of perennial grasses and forbs were present as opposed to areas with grasses alone. This provides evidence that vegetation communities rich with a variety of native plants resist invasion better and further justifies the need for diversity in grasslands and other plant communities. Although the entirety of negative long-term effects of invasive species is unknown, habitat loss, and in some cases extinction of native species, are just a few negative consequences of exotic invasion. In the scope of this project, focusing on restoring one forb species is a small start towards enhancing richness at this site. With the knowledge gained from this project, hopefully future introductions of species can follow.

There are many components to be considered that may pose problems or complications for this project. For one, the difference in past distributions of the Narrow leaf milkweed compared to its current state is not known for all of California. It is currently found throughout the California floristic province with the exception of the entire coastal edge and a section north of the San Jacinto Mountains. There are a few documented populations in Yolo County, but only two of these were documented in recent years with one location east of the McLaughlin UC Reserve. The earlier collections were from 1913, and 1940s through 60s and these were mostly along Country Road 31. In Solano county, there are limited recent accounts of the species, but there are many older documentations from the early 1900s (Jepson Interchange). The lack of recent sightings of the species could be an implication that its distribution has decline in the local region. Having documented species near our restoration site, on a UC Reserve, further justifies this restoration of this species on our site. We can also make inferences about its reduction in distribution from the declining populations of several milkweed species (FWS) as a result of broad herbicide applications (Pearson 2005) and dramatic decreasing populations of the Monarch butterfly (CMS 2004). This is just an inference however, and a lack of accuracy could be problematic if the species at the site has harmful unforeseen interactions with other biota.

This species is considered a weed in certain western states like Wyoming and in some southern states (Whitson and Southern Weed Science Society) which may be of some conflict with implementation of this project. The cardenolides in all *Asclepias spp.* sap are toxic to humans if consumed directly and can be poisonous to livestock. This toxicity, primarily its effect on cows and sheep, was the instigator for why milkweeds were considered weeds in the past (USDA).

In Brown's study of effects of established perennial grasses on introductions of native forbs, success was variable based on planting method. *A. fascicularis* did significantly better when planted from specimens grown in large containers versus small containers or direct seeding methods. Large containers provided better insurance for survivorship in the field, but it was also the most expensive method. The benefit of this method was that the plants could be transplanted amongst established perennial grasses without any harm to the transplants. Direct seeding amongst perennials, however, greatly reduced the growth of forbs. By using pots it also allows for broadleaf herbicide applications up until the time the milkweeds are planted. This method also decreases the immediate competition with exotic species. It is was also noted in this study that after surviving one dry season the mortality rates were very low. Upon returning to the site of restoration several years later, *A. fascicularis* had spread in distribution, and was persisting well.

It is also crucial to consider the life cycle of *A. fascicularis.* As a summer growing rhizomatous perennial, it often takes one or more seasons for plants to build up enough resources to initiate flowering. A lack of flowering in the first few seasons does not imply poor establishment and it is necessary to observe the site over time to really judge the success of plantings (USDA and Brown 2001). There are two options with choosing material to propagate from. One of which is to collect seeds when the follicles begin to split open in the spring (Robson 2008), selecting from a variety of plants in several areas to insure genetic diversity. The other would be to inter mix rhizome cuttings (Robson 2008). This could provide opportunities for individuals, introduced as rhizomes, to be flowering initially, while those planted as seeds are building up resources in vegetative growth for flowering in the following season. This would also start to attract pollinators to aid in future colonizing of the space.

Cultivation of the site with perennial native grasses can be more minimalistic if using Brown's study for a model. *A. fascicularis* in particular did not show a substantial improvement when grown in bare soil versus with background vegetation (Brown 2001). It would be more difficult to plant in plots where exotics have already established however, conferring no competitive advantage for the milkweed and not allowing for herbicide application after the plants are in.

In determining the temporal scale for this project, further research is needed. Brown's study determined, from an informal observation after several years, that without interference or improvement on the site, the plants appeared to be doing well and had grown in population size.

Further research needs to be done to determine funding possibilities. One aspect is to seek volunteer help from California Native Plant Society, and organizations that are helping to protect the Monarch butterfly.

Parts II and III

The short term goal at the Putah Creek Reserve would be to successfully propagate, transplant and ensure establishment of *A. fascicularis* on a few or all of the basin edges. Because this particular species finds many diverse habitats suitable it would be wise to select several of the basins for restoration. To limit the planting scope, choosing to plant on only the outer upper basin edges might be the best approach. This would also be beneficial for projects where the basins will be filled to convert to riparian areas. If a given basin is to be left dry, the seeds of *A. fascicularis,* which are spread by wind, would be more apt to settle in the basin than for the reverse to occur. If a suitable germination habitat was met in the basin this could be a new area for the plants to colonize and part of the long term success of project could be judged by colonizing of basin areas as well.

A. fascicularis is often found growing in clumps in a patchy distribution and it would be best to mimic this pattern in planting. Monarch caterpillars also require dense plantings for survival as they cannot travel far distances between plants (USDA). In Brown's experiment a typical planting distance of 30 cm was the standard distance. The number of plants per basin edge should be determined based on standard population sizes of observed sites with established populations. This could be estimated after visiting known populations in Yolo and surrounding counties that are cited on the Jepson Interchange (found in *A. fascicularis* distribution section, USDA website). The number of plantings will ultimately be dictated by budget constraints and tailored to consider the needs of the other species in this restoration project.

There are a few options for choosing plant sources. One would be to collect seed from local populations, in the late summer months, selecting several sites in nearby counties, to ensure a good genetic mix. If populations are large and thriving at Yolo county sites, it may be best to select only from here to confer any competitive advantage with using genotypes adapted to the local conditions. It might also be feasible to use rhizomes and take cuttings from these same sites for propagation by division. An advantage to using rhizomes is the reliability of success for the most part (USDA), and because the phenotype is apparent, a varying mix of plants could be chosen. Choosing a mix rather than only the visibly hardy plants ensures that under variable conditions one genotype may thrive where another did not. It is also possible to get flowering in the first year with rhizomes (Robson 2008 and USDA) and this could begin to attract

Monarch populations, and provide seeds in the soil bank. The third option would be to get seeds from California native plant nurseries. All of these options could be combined as well if a larger genetic mix was preferred, although using only local populations may confer some advantages of adaptations to regional conditions. The dry conditions and intense summer heat of Davis would be better tolerated by individuals who are adapted to this local climate.

When propagating by seed, Brown's study should be used as a model. It showed that seeds had greatest survivorship when planted in large pots first before planting onto site. Large containers of the same dimensions (13.6 cm deep, 3.6 cm. diameter, (150 ml. vol.) can be obtained from Stuewe & Sons Corvallis, OR. Seeds should be planted in commercial potting mix with a peat and vermiculite base, near the end of October. They should be watered initially and thereafter as needed. The setting for growing is best in a greenhouse, or protected outdoor area. Seedlings can be transplanted in the months of January through March. For transplanting to site, an area should be cleared, a hole dug by core removal, the plant placed in the hole, covered with surrounding soil and then watered immediately (Brown 2001). If rhizome divisions are to be used different timing for planting is needed. They should be initially collected during October when the plant is dormant and immediately placed onto site after cuttings have been made. This protects the root systems, allowing them to develop enough to survive the winter months (USDA). Periodic watering in the first year of transplanting should be done to guarantee proper establishment at the site and to protect from drought in the summer months (Brown 2001).

This species, taking one year or more to garner enough resources for flowering will have to be observed over a multiple year period to judge success. The long term success of this project could be weighed based on varying criteria in the following years after implementation. The first few months after planting should focus on monitoring the transplants, and attending to weed removal directly adjacent to plants and watering to prevent stress in the first growing season. After summer months, observations should be made to take a species count and document any failures to establish that may have occurred in the first year. In the following year, plants should be visited during the growing season to see if flowering has begun. A species count at each basin should be done, and any losses recorded. In the third year or following years, the entire site should be surveyed for possible new populations. Any plants appearing outside the upper edge of the basins would be considered new emerging populations.

Herbicide applications may be necessary in the preparation of the restoration site. Given that the site already has many exotic species prevalent, it may be the most effective management tool initially. If working with mostly grasses initially, spraying a broadleaf herbicide would eliminate some exotic competition. This would have to be done before planting *A. fascicularis* initially and could be done after the summer growing season in the late fall or early winter when the past season's plant material is dead and new shoots have not yet emerged.

In Bowles' study of *Asclepias meadii* mowing and fire were studied as management tools to see the effectiveness with restoration. Annual mowing and fire management selected for different mechanisms of resource allocation. In plots where summer mowing occurred, plant densities were high but flowering was minimal, around

20%. In the populations where fire was utilized, milkweed densities were lower, but a greater percentage of the plants were flowering. Unlike the mowing which occurred after seed-set, the burning occurred in the spring. Burned sites showed greater growth and overall survivorship amongst individuals. This suggests that in mowed populations, where seeds are often consumed, selection favors clonal colonization within the species. In the fire managed communities, more resources were allocated towards sexual reproduction. Both strategies of plant management would have positives and negatives, since both could be utilized in separate plots depending on species needs or in alternating time regimes. Mowing of the site initially would decrease competition from other plants while introducing *A. fascicularis*, and could be beneficial. Long term use of mowing as a disturbance mechanism or as a tool for invasive plant control, may exclude sexual reproduction altogether. A lack of flowering would also have a detrimental effect on pollinators especially the monarch. Adult Monarchs feed on nectar from the flowers (Ladner 2005) and without the flowers present they may not find a suitable habitat. Although mowing, in the aforementioned study, allowed for greater plant densities, gene flow decreased when sexual reproduction was not favored. This could be advantageous if the only concern was species cover and quick colonization. However, genetic crossing insures that many genotypes are present and the system, allowing for greater resiliency to disease, pests, and individual genotypes can occupy a greater diversity of niches within an ecosystem. Bowles' study further confirms the benefits of genetic crossing, as survivorship was greater amongst the species that experienced fire versus those that did not.

Care needs to be taken when considering grazing as a tool for management. The sap in milkweeds can be fatal to livestock if consumed in large quantities. *Asclepias* spp.are not generally palatable to most grazers, but will get eaten if other food is scarce. Consumption of milkweeds is really only of large concern when animals are over grazed in a given area, or during periods of drought when other forage is limited. Sheep and goats seem to be particularly sensitive to the toxicity. Goats can be poisoned after consuming as little as 0.25 to 2% of their body weight in milkweed materials. Some strategic timing of grazing could minimize some of this danger. If an area is grazed in the early winter, after the plants have died back in the fall, this may be safer. Although some residue from the sap is still present in dead stocks, there are likely to be exotic annual species that would be more preferable in taste (Smith 1994). In comparative assays, *A. fascicularis* had lower cardenolide concentrations than other *Asclepias* species (Ladner 2005) which may also lessen the danger of toxic consumption.

In considering mowing, fire, grazing, and herbicide spraying, there is a preferential hierarchy for these management tools. Based on the literature reviewed, fire seems to be the most favorable option, but mowing, grazing, and herbicide applications could be utilized with careful management. Bowles' restoration project suggests a positive correlation with burning done in the spring time. Other seasons may also be beneficial, but research on the difference in timing is limited. Bowles' study only analyzed the effects on growth on plots that were mowed in the summer. This timing was determined beneficial for hay production in the fields *Asclepias* were growing in. The phenology of the species would suggest however that mowing in the late fall, and winter would allow more time for seed dispersal and less seeds would be consumed in the mowing process. Further research needs to done to determine the best timing for herbicide applications. Considering that *A. fascicularis* is rhizomatous and dies back in the fall, it might be less harmful to the plant to spray invasive species in winter when the milkweeds are dormant.

Other species interactions may occur that are not foreseen. Since this species tolerates a wide range of conditions it may be possible that it could out compete other desirable native species which may be of concern. It may also be possible that a large population could interfere with grazing management of other species by posing danger of toxic ingestion. Failure of establishment may occur in the case of a severe drought, or if a pathogen takes over or specialist milkweed insects consume and stress new transplants. In previous restoration efforts the species did best when directly planted from pots and direct seedling did not produce high success rates (Brown). Colonization and spread of the species may therefore be inhibited by the presence of other species. Future management may have to include periodic space clearing in patches to allow for seeds to spread and populations to expand spatially. Adaptations to the restoration plan would have to be made and tailored to new considerations with other species as well. Perhaps the timing of planting would be manipulated by a few weeks to allow for herbicide applications, or to allow for the planting of more sensitive species.

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Restoration Plan for the California poppy (*Eschscholzia californica*) Spring 2009

Part 1

A. Background and Justification

Goal: Establish the California poppy as a stable component of an open California native grassland.

The California poppy, *Eschscholzia californica,* is the state flower of California. It is a widespread and commonly recognized plant, and for many is a treasured symbol of the state. A perennial or annual wildflower, this species typically occurs among perennial grasses and other wildflowers. Its resistance to herbivory (Leger and Forister 2005) and ability to adapt and grow well in a variety of environments are factors contributing to its continuing success. In other parts of the United States and the world, it is considered invasive and undesirable (Leger and Rice 2003).

Grasslands cover about 25% of the state of California, and are currently dominated by annual grasses (Barry 2006). Most of these annual grasses are non-native, resulting in a decline in native species previously present; native species now comprise less than 1% of grassland flora in most parts of California (Barry 2006). These grasslands, originally mixed grass and forblands, have been in decline since the Spanish explorers and missionaries established domesticated grazers at high densities (a trend that California is still struggling to reverse) along with exotic plant species (Minnich 2008). Overgrazing pressure doomed California's meadows and prairies to invasion (Minnich 2008). The dominance of exotic grasses causes severe reductions in populations of native wildflowers like the poppy, although the poppy has proven to be remarkably resilient, and is one of the few wildflowers able to maintain a significant presence (Robbins et al. 1951, Munz and Keck 1959 from Robinson et al. 1995). There have been decreases in poppies due to changes in fire and grazing regimes. There is a reserve devoted to the poppy set up because of marked declines - the Antelope Valley California Poppy Reserve, a State Natural Reserve - which indicates that there is awareness of the need to preserve habitat for the poppy. Like all other wildflowers and any plant material, it is illegal to cut, destroy, mutilate, or remove poppies when found in reserves and preserves, and along freeways and public rights-of-way, and on private property, though it has no special protections in the state of California. (California Penal Code 384a).

As a native California plant, the poppy plays a role similar to that of other wildflowers of providing habitat to pollinator insects. Native bee populations are shown to increase crop yield when a certain amount of natural bee habitat (including wildflowers) is adjacent to agricultural areas (Kremen, 2004). Poppies are pollinated by a variety of bees, beetles, wasps, and ants (Cook 1962).

Native plant organizations, like the California Native Plant Society (CNPS) and California Native Grasslands Association (CNGA) work to promote native plants and their ecosystems through education and organization. The USDA Agricultural Research Service is studying revegetation with perennial native grasses and its benefit to soil and water quality, weed control, and forage (Elstein 2004), and if poppies are a part of the native perennial grassland ecosystem, funding for projects including them may be available. Saving native bees is a hot topic, and resources are being created and organized to effect positive change for bees. Haagen-Dazs Ice Cream even has programs to promote awareness of native bee services and needs. These are potential sources of financial support for a restoration project involving the California poppy.

B. Literature Review

Eschscholzia californica

Papaveraceae

The California poppy is native to western North America, from the Oregon-Washington border along the Columbia River to Baja California, and east from the coast of the Pacific Ocean to the Great Basin, at altitudes from sea level to 6,500 feet (Cook 1962). It occurs on open, well-drained soils of dunes, alluvial fans, river terraces, steep banks, and other rocky places (Cook 1962, 1965). The proposed restoration site in the Putah Creek Reserve in Davis, California is within this range, and contains these types of habitats; therefore, *Eschscholzia californica* is an appropriate species to be included in a restoration plan for this site.

The California poppy can establish on soils from a variety of parent materials, including serpentine (Cook 1965), so long as they are well-drained. Any parts of the restoration site that will not be saturated or have standing water should be acceptable areas to sustain poppies.

Poppies are annual or perennial herbaceous plants 5 to 60 cm in height or spread (Jepson 1993). They are typically annual in more arid regions, especially the western parts of the San Joaquin Valley (Cook 1965). Since Davis is fairly arid, especially in unirrigated areas away from other water sources, the poppy might act as an annual at the restoration site, depending on the ground water supply. Annual individuals send an unthickened root up to eight inches deep to utilize water close to the surface during the rainy season (Cook 1965), which is winter and early spring in Davis. If a permanent ground water supply is available, they produce small rosettes of leaves and soon go to seed (Cook 1962). If not, they develop very quickly, with little leaf rosette formation, and reproduce as soon as possible then die, enduring the hot seasons as seeds (Cook 1962). The poppy might also act as a perennial. Perennial individuals produce a thickened root that goes much deeper (Cook 1961 from Cook 1965) to use ground water all year (Cook 1965) if it is available. If winters are mild, perennial populations will germinate as soon as it rains in the fall, produce a taproot and leaf rosette during the winter, and bloom in the spring (Cook 1965). They will go dormant for the summer and become active again after the first rains in a cycle for several years (Cook 1965). The long taproot does not transplant well, so poppies should be direct seeded on a restoration site; since they germinate with the rains, seeding should be done before the rainy season ends, and possibly before it starts.

Poppies are only as vigorous as available space allows (Cook 1965). The poppy's root system does not efficiently use the top layers of soil, and therefore in moist places species with good surface layer root systems will outcompete it by taking over rootable soil volume and growing faster and shading it out (Cook 1965). This will necessitate a balancing act with other species to be established at the restoration site, in terms of order of establishment and intended densities. Where the water table is high but conditions are less favorable for other species like grasses, such on sand and gravel bars of streams, poppies may grow (Cook 1965), though the riparian and potential wetland areas at the

Putah Creek Reserve are mostly not of this raw land type, but are more nutrient-rich and already vegetated.

California poppies are flexible in their development because they retain enough plasticity of characteristics to adapt to diverse conditions (Cook 1965). They adapt so quickly and strongly that there are colonies that are considered different populations as close as half of a mile to each other (Cook 1962). On the restoration site, one seed source may evolve into several populations if conditions vary enough to necessitate adaptation, which is beneficial to the managers of this site, as they will not have to pre-select and seed differently adapted populations for different parts of the site. Even populations from non-serpentine soils can develop well and reproduce on serpentine soils, and vice versa, with apparent indifference (Cook 1965). The poppies will develop and breed as obligate outbreeders (Cook 1962) for the most successful phenotype for their individual location. This is particularly true if the plants are acting as annuals, as it has been shown that annuals may retain a tendency toward outbreeding, which is related to their occurrence in large colonies, which is related to their preference for open communities (Cook 1962).

Site factors, especially abiotic factors (Leger and Rice 2003) such as soil characteristics (Montalvo et al. 2002) down to the microsite scale (Robinson et al. 1995) affect establishment, growth, phenotype of roots and shoots (Cook 1965), and survival, and can vary extensively over a small scale (Montalvo et al. 2002). Adequate preparation of the restoration site to ensure proper soil and microsite conditions will directly influence the success of the California poppy. This is no small task, if it is even possible. If plants are stunted and red leaf coloration occurs, there may be a nitrogen or phosphorus deficiency (Montalvo, et. al. 2002). Percent cover is strongly related to soil nitrate concentration (Montalvo, et. al. 2002) and nitrate levels should be assessed initially and addressed continually as part of a monitoring program. Total density of the poppy has been shown to decrease with increasing percentage soil organic matter (Montalvo, et. al. 2002), which should also be monitored. This may also be a function of competition, as many species prosper in soils high in organic matter.

Poppies and grasses are often associated (Cook 1965). They begin growing in the cool seasons after winter rains at about the same time; in dry years poppies proliferate, and in wet ones grasses develop well and dominate (Cook 1965). Poppies and grasses both favor full sun and no shade for best growth (Cook 1965).

Poppies are adapted to direct sun in hot, dry climates, with glabrous, sometime glaucous leaves that are linearly dissected (Jepson 1993). The leaves and flowers of the poppy are toxic but rarely eaten (Jepson 1993) because of several alkaloid compounds that deter herbivores (Leger and Forister 2005). Ergo, poppies are a poor food source for grazers. Also, the presence of grazers may have a negative effect on poppies. Poppy plants have difficulty germinating in grazed areas (Robinson, et al. 1995). Though grazers remove biomass that would otherwise overtop or shade out poppies, this is not enough for them to establish; the compacted, poor quality soils that can result from grazing lack the appropriate microsites for germination (Robinson, et al. 1995). Though knowledge of the enemies of the California poppy is incomplete, there is some evidence of insect herbivores preying on poppies (Leger and Forister 2005). Several cases reported generalist Lepidoptera using the California poppy as a host (Leger & Forister

2005). The geometrid moth *Neoterpes edwardsata* Packard may be a specialist on California poppies: it has a restricted host range, larvae have been found on poppies, and the larvae resemble the flower buds of the poppy (Leger & Forister 2005). Insects do not eat adult poppy leaves, although slugs and snails do not hesitate to eat seedlings (Leger & Forister 2005). The resulting high mortality during the seedling stage because of damage by slugs and snails (Leger and Rice 2003) can be a serious setback in an attempt to establish a population. Bait and deterrence methods have been successfully used to address these issues (Leger and Rice 2003). These will probably not be prohibitive to the establishment of poppies at the restoration site, though it may be wise to include a casual visual survey for signs of these predators in a monitoring plan, especially in case the poppies are not doing well, and re-seeding may have to be done if a large enough portion of the population is affected. Unusual conditions, such as winter drought (Robinson et al. 2005), prolonged frosts, heavy rains that cause flooding, and low temperatures with snowfall can also kill off a generation of seedlings and necessitate re-seeding the following year (Leger and Rice 2003).

No vegetative reproduction occurs in this species (Cook 1962). It depends exclusively on sexual processes for successful reproduction (Cook 1962). In studies, new individuals were chiefly found near reproductive individuals from the previous season; fewer than half of new individuals most years survived to reproduce (Robinson, et al. 1995). A short-lived seed band is the main source of annual regeneration, which corresponds directly with yearly variation in weather and conditions (Bartolome 1979 from Robinson, et al. 1995). A dry season the second year after planting may produce stunted or unreproductive individuals (Montalvo, et. al. 2002), though under optimal conditions the plants can become quite large and produce an abundance of flowers (Cook 1965), so it is important that populations are monitored for reproductive success and new individuals to determine if they are perpetuating. If they are not successfully propagating themselves, checking if they are being pollinated and producing seed are important steps to identifying problems. Flowering time is February to September according to Jepson (1993), or March to October according to Cook (1962). Flowers shed their petals after pollination, leaving a crown-like membrane (Jepson 1993), which may be useable as an indicator in a monitoring program.

California poppies have large, showy flowers that can be any color from solid orange to solid yellow (Jepson 1993), and petal color varies geographically: they are mostly yellow in the north, the mountains, and on the coast, and more orange in the south, in interior lowlands, and northward along the western side of the Sacramento Valley (Cook 1962). The transition from one color to another is gradual geographically (Cook 1962). In selecting a source population for seeds for restoration, the appropriate color should be chosen, which for Davis is mostly orange.

Though the pollen of the California poppy is the right size and shape for wind pollination, and is produced in appropriately large quantities, the majority of pollination is carried out by insects (Cook 1962). Ensuring that the appropriate pollinators are present may be critical in predicting the success of a restoration plan. In some situations, like vernal pool restoration, the absence of the necessary pollinators can result in the failure of the project. Luckily, poppies have been observed to have a broad range of pollinators, and many of them (Robinson, et al. 1995), though knowledge of pollinators is incomplete (Cook 1962). Nectar is a free bonus for pollinating a given flower, some easy energy to keep going, which makes the daily struggle of an insect just a little bit easier. Poppies produce no nectar (Cook 1962), and therefore do not provide this support to pollinators. Nonetheless, beetles feed and mate on the flowers in early spring (Cook 1962), and Grant (1950, from Cook 1962) even categorized poppies under beetle-pollinated, though Cook (1962) found honeybees (*Apis*), bumblebees (*Bombus*), and hymenopteran families Halictidae and Melittidae more significant pollinators than beetles. There are four or five species of solitary panurgine bees (genus *Perdita*) that gather pollen only from *Eschscholzia californica*, or from it and *Calochortus splendens* (Timberlake 1956 from Cook 1962). Also, thrips (Thripidae) (Cook 1961 from Cook 1962) and hover flies (Syrphidae) (Knuth 1908 from Cook 1962) have been observed visiting the poppy (Cook 1962). It may be beneficial to these species to ensure recurring populations of poppies.

The fruits of California poppies are 3–9 cm long cylindric capsules (Jepson 1993), which are explosively dehiscent from the clasping receptacle at the base of the fruit (Cook 1962). Cook 1962 states that this is the only apparent dispersal mechanism, though at another point mentions that the seeds (which are brown and ridged, spherical and under two millimeters in diameter (Cook 1962)) can be moved by wind and water, which are not uncommon dispersal methods. Elms and maples rely almost exclusively on the natural elements to move their seeds, and though the poppy's seeds are not as well suited to wind or water dispersal, they do not become wetted easily and do float (Cook 1962). There is no mention in the literature of insects, mammals, birds, or other animals playing a role in fruit or seed dispersal. A capsule's dehiscence scatters seeds in up to a five foot radius (Cook 1962), which could be factored into a seeding plan for spatial patterns of distribution. Perhaps a project could use half as much seed and do rows at a given density but skip every other row, and the poppies might fill in the gaps. If there are other species in the restoration plan that require seeding or planting in clumps or other massings, they could be distributed in alternating swaths with poppies.

Seeds require darkness for germination (Cook 1965); germination is inhibited by light (Goldthwaite et al. 1971 from Montalvo, et. al. 2002). They germinate best around rocks and pebbles, which catch seeds and provide darkness (Cook 1965). Seeds may have a high degree of dormancy, though the degree of inhibition of germination varies geographically (Cook 1962). The highest levels of inhibition occur in seeds from arid climates of both annual and perennial populations (Cook 1962). Interior areas of the state of California also have higher degrees of dormancy (Cook 1962). Dormancy is probably genetically determined (Cook 1962), which may be a relevant factor to consider in determining a seed source, although it may also be a difficult factor to properly select for. There are no known natural mechanisms for breaking dormancy, though germination may be induced with the growth hormone gibberellin (Cook 1962).

The availability for purchase of large quantities of non-bred native varieties of commercially grown California poppy seed that are of high quality (Robinson, et al. 1995) makes implementing a restoration plan that much easier, since the restoration manager will not have to deal with setting up a nursery to get enough of the proper type of seed, or paying someone else to do so. Robinson, et al. (1995) seeded at a density of 500 seeds per square meter; Montalvo, et. al. (2002) at 66 live seeds planted per square meter. The former seeded heavily to allow successful invasion of established grass plots, and the latter was using a mix of several species, which is seems light by comparison, but may still be sufficient for the poppy to establish, especially in the context of a mix of other species also trying to establish. A calculation involving proposed abundance and density of species should be performed which considers likely germination success and seedling mortality (Montalvo, et. al. 2002) for the restoration site. A study that yields the optimal seeding rate for poppies in a variety of vegetation densities and environments would be valuable to future restoration projects.

Though a high volume of seeds may be produced the first year, they may be unable to germinate and reproduce successfully the second year (Montalvo, et. al. 2002). Monitoring is necessary, and re-seeding may be a reasonable course of action, although viable seed may remain in the seed bank and may germinate in future years (Montalvo, et. al. 2002).

There was no mention in the literature of poppies requiring fire treatment. It appears that it tolerates burning, and is not eradicated by it. The poppy can colonize burned areas and remain for several years (Bowerman 1944 from Cook 1965). Its appearance after fires may be from a release from competition (Cook 1965) until other species return.

Poppies are able to establish and be successful reproductively on sites with greater species diversity and a lack of a dominant species (Robinson, et al. 1995). Under optimal grass conditions, the poppy is unable to invade or sustain itself among established grasses (Cook 1965). If planted at the same time as poppies, grasses like oats will suppress poppy growth by shading out poppy seedlings with superior initial shoot growth (Cook 1965). In studies with *Bromus diandrus* Roth, poppies were only able to germinate one-third as much in areas dominated by *B. diandrus* as in other areas (Robinson, et al. 1995). Grasses are able to do this because of their larger seed size, though they must be superior in numbers and effect continuous cover to successfully suppress poppies (Cook 1965). However, poppies have been observed in grain fields, where they are able to grow because mowing removes the overtopping grain (Cook 1965). Poppies are partially given an advantage by mowing, because they are given the light resources to grow that the grasses would have used if they were dominating. The poppies are cut back, but new shoots emerge from low on the plant, and they are able to flower for the second half of the flowering season, from mid-summer to fall (Cook 1965). If grass was not dominating, poppies are set back because they will have lost half of their potentially reproductive season. In a restoration plan, poppies should be seeded before grasses are established, or a mowing regime should be implemented to give the poppies a chance to grow and reproduce among grasses.

Disturbance by small mammals, such as burrowing and trampling by ground squirrels, affects grassland species composition (Robinson, et al. 1995). Germination is better where disturbance is greater (Robinson et al. 1995), though small mammal burrows can result in seedling damage (Leger and Rice 2003).

Few interactions with other species are mentioned, aside from negative associations with grasses, but seedlings of *Lupinus* and *Eschscholzia* were noted at similar times in similar conditions (Montalvo, et. al. 2002).

Montalvo, et al. (2002) tested a variety of site treatments and seeding methods, which resulted in various recommendations. It is emphasized that these recommendations are only for similar site and species conditions.

A ripping treatment, consisting of three treatment levels (no rip, 20-cm deep rip, and 40-cm deep rip) was performed on moist soil just before seeding by ripping blades spaced 25 cm apart with their depth controlled by hydraulic lifts pulled by a small Caterpillar tractor in rows. This resulted in showing that
although perennial *Eschscholzia* has high density and cover with the 40-cm rip treatment, which is probably because of higher survival and growth with the treatment, soil ripping does not affect establishment. However, it may be appropriate on graded, compacted soil, in conjunction with soil amendments to increase soil organic matter and nutrients as appropriate to remediate conditions in the restoration area. If graded, compacted areas at the restoration site are to be incorporated into the meadows, this treatment may be beneficial, though it is only recommended for similar sites and seed mixes.

A mulch was applied, which consisted of blowing rice straw over planted
areas a rate of 1,680 kg/ha (1,500 lb/acre), which is about 76% of the amount proven effective in reducing erosion (Miles et al. 1989; Robichaud et al. 2000 from Montalvo et al. 2002) and about 50% of some rates from Caltrans (Brown et al. 2000 from Montalvo et al. 2002) in hopes of not creating a mulch layer that was too deep for species to germinate, and a hydromulch slurry of water, wood fiber at 340 kg/ha (300 lb/acre), and a soil stabilizer at 135 kg/ha (120 lbs/acre) sprayed over the straw. Since all treatments and seeding methods received this mulch, there are no recommendations for or against its use.

Three seeding methods were used: hydroseeding, drilling, and imprinting.

Hydroseeding is recommended for steep slopes and rocky areas where imprinting is difficult, with seed mixes consisting of small-seeded species, as it is a high cost method and not the most effective. This treatment resulted in seeds placed at the surface of the soil, embedded in hydromulch 0.5–10 mm thick, which has desiccation and predation risks for the seeds. A seed mix with 25% more seeds because of aforementioned risks, water, and green-dyed wood fiber slurry was sprayed at 560 kg/ha (500 lb/acre) sprayed over prepared soil.

Drilling is not recommended because it resulted in significantly lower densities than the other two seeding methods. Drilling buried seeds about 10–12 mm deep, which may have been too deep. The poppy was expected to perform better with drilling treatment because light inhibits poppy germination, according to Goldthwaite et al. (1971), but other, shallower seeding treatments resulted in higher poppy densities. The seeds were commercially cultivated stock, and it is possible that the source population may not have had light inhibition to germination, because of alterations from domestication practices, as differences have been seen between wild and cultivated California poppy seeds (Victor Schaff, personal communication 1999; Montalvo personal observation 2000 from Montalvo et al. 2002). Seeds were drilled to a depth of 6–12mm over the prepared seedbed using a Truax no-till range drill (Truax Company, Inc., Minneapolis, MN) with six drilling disks after being mixed 1:1 with wheat bran to provide bulk and promote even distribution of seeds from the drill box. When combined with ripping treatment, a small Caterpillar tractor was driven over ripped areas to smooth the gouges created by ripping to create a more even surface. Though there was some minor compaction near the surface from the tractor, this was loosened by the seed drill.

Imprinting had the most consistent results of the three treatments. It yielded the highest percent cover of poppies in second year surveys. It should be the favored method if species composition and site conditions are similar to those in the study. It is best on flat-to-gently sloping areas with seed mixes of small-seeded species and species that require light for germination. This treatment results in seeds pushed into the soil to just below surface. The Dixon imprinter's (The Imprinting Foundation, Tucson, AZ) seeding box was too large to evenly spread seeds over areas smaller than 0.5 ha, as was the case with the test plots, so the seeds were mixed 1:1 with bran and hand broadcast, then imprinted immediately. For larger plots, hand broadcasting would be unnecessary. The imprinter was weighted to leave 10-cm deep impressions in the ripped areas. In the unripped areas, compaction only permitted imprints approximately 5 cm shallower than in ripped areas.

Monitoring approaches may be borrowed from certain studies. Robinson, et al. (1995) took percent cover samples in late spring, and included plant litter and living vegetation. Montalvo, et. al. (2002) sampled May-July the first year and January-May the second year. Samples were only taken from the central part of the test plot to avoid edge effects. A sample quadrat method was used to measure plant density and percent cover. If density dramatically decreases, quadrat size may need adjustment. Individuals of selected species were counted in 0.5x1.0 m quadrats in mid-May. A transect method was used to randomly select sample plants for measures of size and reproductive status. Density was standardized to number of plants/m sq for all analyses.

Part II

A. Goals

-Establish the California poppy in open, well-drained upland areas, including rocky and steep areas, on any soil type, including serpentine if it is present in the Putah Creek Reserve restoration site. Avoid shaded areas and waterlogged areas. The ideal locations will eventually be determined by the poppy itself, based on where it is able to be successful, so as much area as possible should be seeded, then (annual climatic conditions dependent) only successful areas should be monitored for continuing presence.

-Have a recurring population, whether it is an ephemeral annual or an established perennial, or changes depending on the conditions of the year and the availability of ground water in a given spot. Knowledge of ground water flows may be used to predict locations of perennials; a study surveying these areas and their incidence of perennial poppies would benefit future restoration planning.

-Prepare soil to be low in organic matter and to have sufficient quantities of nitrogen, phosphorous, and other necessary compounds and minerals, and to be ripped and otherwise as de-compacted as possible. Proper microsites, with enough darkness for germination, are also ideal. Distribution of rocks and pebbles can help achieve such microsites, although the benefits of strewing rock around a site, especially one that may be mowed, is quite questionable. This is a huge task, spatially and financially, and there is a good chance that the poppy will be able to exist on whatever is currently there, and that such extensive soil preparation will make the areas easier for other invaders, which may outcompete the poppy. Monitoring for soil organic matter content and nitrogen content continually would be good, but it is even more difficult to amend soil once plants are established, so this would be chiefly for data collection purposes.

-Use only direct seeding methods to introduce to the site the first year and any necessary following years, and do so before the end of the rains. Seeding method will have to vary in succeeding years to not disturb other plants unnecessarily. Do not use seedling transplants because it would be waste of resources, poppies are more likely to succeed if direct seeded.

-Balance the timing and spatial distribution of introductions of other species to minimize direct competition with the poppy. Seed poppies before grasses, or at same time and then mow. Even if poppies are established first, if grasses are consistently, year after year, overtopping poppies and severely limiting their growth and success, mowing may be necessary. Annual grasses may be more problematic to poppies than perennial grasses, though both may be an issue.

-Monitor to identify if different populations form, and to isolate the factors that cause this, to inform future restoration work.

-Monitor for insect herbivory

-Avoid grazers, especially heavy ones, as they ruin microsites.

-Monitor for slug and snail predation on seedlings, and employ bait and deterrence methods as necessary to reduce damage, and reseeding that year or the succeeding one as necessary to bolster recruitment.

-Monitor long-term for unusually harsh years, and even if consistent monitoring has ceased, perform some type of survey to ensure that poppies pulled through. If not, reseed.

-Monitor for reproductive success and recruitment. Evaluate seed bank annually. If not reproducing or recruiting, check pollination success using crown-like membrane and absent petals indicator, presence of pollinators, and check viable seed production numbers. If poppies are producing viable seed, the manager should not have to worry about adequate dispersal, as individuals close to the parent plant should not overly challenge the parent plant for resources, and the mechanisms of explosive dehiscence and wind and water movement should be sufficient and reliable enough to distribute the seed.

-Ensure all seeds being distributed at the site are from an appropriate source: are non-bred, native to the area, come from stock that is the right color (mostly orange) for the region, and probably with high dormancy. All but the last factor should be easy to control for, and are very important to control for. The last one is mostly an issue of predictability, which can be difficult to control even under 'known' circumstances. A gibberellin treatment may be performed on the seeds, though if a high quality seed source is used, this should not be necessary.

-For initial seeding, distribute in regular or irregular patterns, leaving voids of unseeded areas between swaths of seeded areas, at a medium to high density of seeds (200-500 seeds per square meter? These numbers are based on rough approximations from an extremely small sample of options, and should be investigated further and properly determined based on desired abundance and species density and expected germination success and seedling mortality. This restoration project could provide data toward optimal seeding rates for poppies at a variety of vegetation densities and environments). Plan voids to accommodate other species that require implementation in clumps or masses. Monitor to evaluate if poppies remain only in distributed areas or if they disperse to even cover, or to different groupings (and in response to what factors? edaphic? crowding?).

-There is no need to burn the site as either preparation before seeding or as a management strategy once poppies are established, unless it is the best way to remove vegetative cover inhibiting poppy establishment. If other species require burns, poppies can be part of a burn cycle, and may appear more abundant, even if not actually better established. Burns may eliminate perennial individuals, which may be a hardship to the seed-producing constituency. Burning in mid-summer, fall, or during winter, as long as it is a single burn and not multiple, should not severely impact poppy reproduction. As long as they have the chance to flower, fruit, and produce seed, the reproductive season may be considered a success.

-Mowing is probably the best way to reduce vegetative cover for the poppy. Mowing at whatever time of year grain is cut, probably the end of summer, has been proven to permit successful poppy growth and reproduction, though other times may also be fine for poppies, similar to burns. Mowing or burning may be necessary if grasses are established first or are dominating excessively.

-Small mammal activity has positives and negatives for poppies, and should not generally be fretted about. If there is an excess of small mammals, they may cause enough disturbance to affect the poppy population. A visual inspection should be enough to establish that burrowers are the problem; bait and deterrents should be used, or the natural predator snake and raptor populations should be bolstered to decrease the population.

-Conduct a more thorough review of the literature on lupines and poppies, and assess the benefits of their interactions, and apply to the restoration plan as appropriate.

-A ripping treatment is not vital to the success of the poppy, so if resources are in short supply, as they often are, this treatment may be left out of the restoration plan. It affects plant success only on an annual basis, which may be significant for poppies, if it causes them to produce higher volumes of viable seed. It does not affect establishment of perennial individuals, but that may not be important for poppies. Further evaluation of this treatment in regards to the long-term success of the poppy is necessary.If it is to be used, a deep rip of approximately 40 cm is best.

-Some type of mulch is beneficial in almost all plantings. Any mulch may be used, so long as it is not applied so thickly as to bury seeds too deeply to germinate. This opens the possibility of using materials at hand, which may be a significant cost-saving factor.

More research is necessary on mulches, as is a look at the preferences of other plants to receive the mulch.

-Imprinting should be the preferred seed distribution method of the three covered for most of the flat or mildly sloped areas on the restoration site. Hydroseeding is appropriate on steep slopes and rocky areas, and an increase in seed distribution density is suggested along with this treatment. Drilling should not be used. Other techniques may be more or less effective.

-Sampling techniques should include percent cover samples taken in late spring, even if mowing, burning, or grazing has occurred, and should include plant litter and living vegetation. Samples may be taken at any time of year, as long as phenologic factors are considered. Samples taken in late fall and early winter may reveal information about perennial individuals. Samples taken in winter or spring will reveal information about germination and growth rates. Samples taken in spring and summer can reveal flowering and fruiting data. Sampling locations should be analyzed for edge effects. Edge effects are not necessarily to be avoided, but must be considered. A sample quadrat method is appropriate to measure plant density and percent cover, though quadrat size should be adjusted if density decreased severely. Quadrat size should be determined based on factors it is sampling for. A transect method is appropriate to randomly select sample plants for size measurements and assessment of reproductive status. Density should be standardized for all analyses.

-In an ideal world monitor for everything. In the real world, monitor for a few factors that are most indicative of enough presence to persist with minimal management, ideally in a self-sustaining system that requires no management.

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ENH 160

Gumplant (*Grindelia* spp.)

Background and justification

The broad goal of this project is to establish an adequate number of viable and sustainable populations of gumplant at the restoration site. Gumplant is a native perennial herb that complements native grass communities. It provides an excellent source of pollen and nectar for native pollinator species (The Nature Conservancy, 2002). Moreover, it is classified as being of high value for wildlife (Fire Safe Council of El Dorado County). It is also valuable economically as a source of harvestable resin that can be used in place of pine resin for use in printing inks, adhesives, and soap (Berti, 1993). The gumplant species native to California's Central Valley, *Grindelia camporum*, is not considered threatened, although it has experienced substantial habitat loss along with native grasslands. Other species of *Grindelia*, native to the desert southwest, are threatened due primarily to water shortages due to human water use (Hickman, 1993). Currently, Central Valley grassland habitats are dominated by introduced annual grasses instead of the native mix of perennial grasses and forbs. Native species only cover approximately 1% of their historic range. Besides invasive species introductions, native grasslands have been altered and/or destroyed by agricultural development, urban expansion, altered hydrology, grazing, and changing fire regimes (McGinley, 2008). Because *G. camporum* is not threatened, there are no local or national policies concerning its protection and use in restoration projects. This may actually be beneficial to using this species in restoration, as many policies, with their numerous restrictions and specifications, make species more difficult to use in restoration projects. *G. camporum* is still a beneficial native plant, and many organizations strive to support its continued persistence through conservation and restoration. Such organizations may be used as funding sources for this project, including: The California Native Plant Society, The Nature Conservancy, and The California Native Grasslands Association.

Literature Review

Grindelia is a lush forb with shiny, dark green leaves. It generally reaches a height around 3 feet tall. Both the leaves and flower heads are sticky due to their high resin content. In late summer, *Grindelia*'s bright yellow flowers, which resemble many other flowers in the family Asteraceae, are attractive to both pollinators and the human aesthetic (Hickman, 1993)(personal observation).

Like many other native species used in grassland restoration, the establishment of *Grindelia* species has many obstacles and constraints. Concerning solely physical site conditions, *Grindelia*, and *G. camporum* in particular, can generally only grow in areas with excellent soil drainage; it cannot grow in heavily-compacted or water-holding soils. Because of this, it does not usually occur in wetlands (The Calflora Database, 2009). However, *Grindelia* is able to tolerate levels of salt that are detrimental to many other plant species. It grows in many salty environments, including saline and sandy bottomlands, fields, and roadsides (The Calflora Database, 2009). Plants need almost full sun, and can easily tolerate afternoon sun. *Grindelia* does not tolerate cold temperatures. (Hickman, 1993), (The Calflora Database, 2009). *Grindelia* is also drought tolerant – a very beneficial trait in California's Central Valley. *Grindelia* is restricted to the valley and foothill zones, at elevations below 3000 feet (Fire Safe Council of El Dorado County).

Physical site conditions, however, are not the biggest constraint on the establishment of *Grindelia* – previously established weeds are. Competition with exotics, and even native perennials, for light, water, and nutrients greatly hinders seed germination and seedling survival (Brown, 2001). Also, *Grindelia* competes with several exotic thistle species for pollinators. Therefore, if exotic thistles are present in a site where *Grindelia* is restored, it may be more difficult for *Grindelia*'s pollen to spread via pollinators, a major problem for a species that only reproduces through cross-pollination (John F. Barthell, 2002). This pollinator competition needs to be studied more extensively in order to determine if *Grindelia*'s fitness is actually significantly reduced when thistles are present.

Clearly, weed cover must be reduced before *Grindelia*, or any other native species, can be established (Brown, 2001). One of the major issues in establishing native forbs in grasslands is that the main method used to eradicate broad-leaf exotic species – spraying with herbicides – also kills broad-leaf native forbs. To prevent this, and still be able to use herbicides as an effective invasive control measure, native forbs must be planted after the establishment of native perennial grasses, when broad-leaf herbicides are no longer needed (Brown, 2001). This method is highly recommended when restoring forbs, but the tradeoff is that the expected final cover of natives will take longer to establish due to staggered planting times, allowing more time for exotics to re-invade the area.

Even when weeds are relatively absent, forb establishment in native perennial grass stands is low primarily due to shading from the taller grasses (Brown, 2001). Different methods of planting or seeding, such as broadcast seeding and transplanting plugs, affect germination and growth rates. Also, many forb species, including *Grindelia*, have seeds that persist in the seed bank for extended periods of time, and may be able to germinate once conditions are ideal. Because *Grindelia* has high germination rates and seedling vigor, use of direct seeding may be the easiest, most cost-effective method to introduce it into an environment without an adequate viable seed bank (Brown, 2001), (Kenneth Lair, 2006). However, forbs generally establish a higher cover in established perennial grasslands when planted as transplants or seedlings, versus direct seeding (Brown, 2001). Mowing or burning before planting forb transplants or forb seeding may help their initial growth and establishment (Brown, 2001), most likely due to decreased shading and above-ground competition.

Most native perennial forbs do not tolerate grazing once mature (Hayes, 2003), but *Grindelia*, due to its resinous flowers and leaves, is not generally eaten by grazers, and is therefore tolerant of domestic grazers (Kirkland, 2007). Also, *Grindelia* is tolerant of grazing by deer (Fire Safe Council of El Dorado County). Due to its lush vegetation, *Grindelia* generally slows grass fires, and is tolerant of occasional fires (Fire Safe Council of El Dorado County).

When *Grindelia*, and other forbs, become established alongside native perennial grasses, they are effective in reducing weed establishment and cover. Although forb percent cover is generally low when seeded into established perennial grasses, the forbs are a crucial part of the mix, as native perennial grass cover alone does not always significantly reduce weed cover (Brown, 2001). This is most likely due to the fact that more ecological niches are filled in a grass and forb combination, effectively reducing the niches available for colonization by exotics. *Grindelia* is often used as an indicator species for successful weed eradication due to its sensitivity to competition from weeds (Kenneth Lair, 2006).

Grindelia camporum has been widely used in the restoration of California's Central Valley grasslands, with differing success rates. In a restoration project in Fairfield, *G. camporum* was seeded at 2 pounds/acre, yielding 35% germination, into wetland basin slopes. This was one of the lowest germination rates for natives in the seed mix used (The Nature Conservancy, 2002). Perhaps the wetland soils held too much water and didn't have adequate drainage. This could be a problem in certain areas of the Putah Creek restoration site. Also, the seeding density in this experiment was low, and success may have been improved with an increased density. In other restoration projects, *Grindelia* establishment in native grass stands has been successful (Baye, 2005), (Russell Ranch Mitigation Area Design Concept Committee, 2002), (The Nature Conservancy, 2002).

Whether *Grindelia* is used in restoration for weed control, attracting pollinators, or enhancing the overall diversity of grassland systems, it is a beneficial part of the vegetation community. Its ability to grow in hot, dry, and salty conditions makes it more feasible for use in stressful environments than other native forb species. As a natural part of the Central Valley flora, its use in restoration should be encouraged and continued.

Goals

The main goal in the restoration of gumplant is to establish several viable and sustainable populations throughout the restoration site. As gumplant can only grow in well-drained soils under full sun (The Calflora Database, 2009), its distribution should be limited to areas with high infiltration rates, relatively low soil moisture, and without shading from larger woody species. Areas at the restoration site fitting these criteria include the upland areas of basins 2, 3, and 4, as well as along roadsides that are not heavily compacted. Inside of the basins, infiltration is generally low (meaning water is held longer in the soils) and, therefore, soil moisture is generally higher, making these areas unsuitable for gumplant. Basin 1, based on its prevalence of wetland vegetation, is too wet for gumplant. Basin 5 has a large amount of woody vegetation in the upland area that would inhibit gumplant establishment due to shading. Gumplant also grows very well in salty soils (The Calflora Database, 2009), so it should be planted in salty areas that may otherwise not have any suitable native vegetation.

In order to increase the diversity and habitat suitability of a site with restored gumplant, it should be planted alongside native perennial grasses (Brown, 2001). If an upland area ideal for the establishment of gumplant already has established native perennial grasses, as several areas do, the establishment of gumplant could be accomplished within the first year of restoration, assuming that broadleaf herbicides are no longer needed or used in established perennial grass stands. However, gumplant cannot establish in very dense perennial grass stands that prevent light from reaching germinating seeds or seedlings (Brown, 2001). If upland areas do not already have established perennial grasses, the restoration of gumplant will take at least two years. First, exotic species must be removed, often through the use of broadleaf herbicides. Then native grasses must be seeded or planted, and further treatments of herbicides may be needed to reduce competition from broadleaf exotics, such as mustard and yellow star-thistle. Once native grasses are established and broadleaf weeds are inhibited to the extent that broadleaf herbicides are no longer needed, gumplant may be seeded or planted into a site.

There is a good potential for the successful establishment of gumplant in the restoration site. Most of the site is or will be restored to native perennial grassland/forbland – gumplant's ideal habitat (The Calflora Database, 2009). Also, there are relatively few large woody species that shade the undergrowth, so gumplant's requirement for full sun should not be problematic. Gumplant is tolerant of grazing (Fire Safe Council of El Dorado County), which will likely be used as a management tool in at least some parts of the site.

However, there are several constraints on gumplant's establishment. Many of the basins and surrounding areas are too wet for gumplant, which appears to be its biggest spatial limitation. Also, if exotic thistle species are prevalent (which milk thistle is in many areas) and are not eradicated before the establishment of gumplant, there could be intense competition for pollinator species (John F. Barthell, 2002). If gumplant does not attract sufficient pollinators, it will not be able to reproduce, and the goal of viable and sustainable populations will not be possible. However, even if thistles are very prevalent, the threshold for pollinator competition with gumplant may not be reached and there could be an adequate number of pollinators to satisfy the reproduction requirements of both thistles and gumplant. It is not known how many thistles or how few pollinators constitute this threshold.

Restoration plan

As there are many reasons why gumplant should be restored to the Putah Creek Reserve, there are many methods and recommendations for *how* to restore it. The first choice is whether to use seeds or transplants of seedlings. Seeds are easy to plant, relatively inexpensive (not compared to grass seed, but compared to gumplant seedlings), and have high germination rates (Kenneth Lair, 2006). For a project with a limited labor force and a small budget, seeds are the best choice. Transplanting seedlings, however, generally yields a greater overall cover of gumplant (Brown, 2001). For a restoration project with fewer labor constraints and more funding, or for a site where it is difficult to establish gumplant, seedling transplants are the best choice. Seeds should be planted in early spring and seedlings in late spring, with enough time before extreme heat for the plants to establish themselves in their environment (Kenneth Lair, 2006). Regardless of whether seeds or seedlings are used, local genotypes should be selected over non-local genotypes. For the Putah Creek Reserve, there are convenient locations just outside of Winters in which to obtain either seeds or seedlings: Hedgerow Farms, which grows crops of native plants from native genotypes and harvests their seeds; and Audubon California, which has a native plant nursery and is actively involved in many local restoration projects.

A second choice involves planting arrangement and density. When seeding or planting gumplant into an ideal site, it is best to attempt to establish a heterogeneous mix of native grasses and forbs in contrast with homogeneous patches of one plant type (grass vs. forb) next to patches of another; this helps to reduce overall weed cover (personal research, unpublished) as well as provide more natural vegetation for wildlife. The exact density of seeding or plantings is not the same for every restoration project, and depends on the mix of other species at the site and their relative competitive abilities. Previous restoration projects have planted gumplant seedlings at distances 0.25 to 1.0 meter apart from each other, with successful establishment (Baye, 2005). When using seeds, seeding rates for native forbs should generally be higher than those used for native grasses, with a minimum forb seed density starting around 8 pounds per acre (Russell Ranch Mitigation Area Design Concept Committee, 2002).

Gumplant should be planted mainly on sunny uplands, where soil moisture is low (The Calflora Database, 2009). The minimum number of individuals that constitutes a viable population of gumplant is unknown, so the goal should be to establish anywhere from a few to many individuals across as broad a geographic range as possible to facilitate overall diversity; namely, to attempt to establish at least some gumplant wherever its growth conditions are ideal. Based on the current vegetation sampling and soil analysis data, these areas include the uplands of basins 2, 3, and 4.

Once established, gumplant requires minimal active management to continue its survival and competitive ability. As long as it is not completely shaded out by taller species, gumplant can withstand drought, salinity, fire, and grazing (Fire Safe Council of El Dorado County). The exact frequency of fire that is not harmful to gumplant is not known, but on a scale from 1 to 10, with 1 being extremely fire resistant and 10 being extremely harmed by fire, gumplant scored a 3 (Fire Safe Council of El Dorado County). Therefore, it would most likely tolerate the frequencies of fire that would be intentionally used as management tools, or that would occur at the site through other means. Gumplant is known to be tolerant of grazing by both cattle and deer (Fire Safe Council of El Dorado County), but no specific research was found on the effects of sheep and goat grazing. Goat grazing in particular may potentially be harmful because goats eat many plants which cows do not, and the reason gumplant is tolerant to cattle grazing is that cows do not eat it due to its high resin content (Kirkland, 2007). However, even if goats do eat gumplant, they may not eat it in amounts high enough for it to be detrimental to its broad restoration goal; they may not exceed gumplant’s grazing tolerance threshold.

Monitoring should be conducted both before and after the establishment of gumplant at a site. Beforehand, a thorough vegetation survey should be conducted, taking note of noxious invasives that require extensive eradication efforts. The overall vegetation types within microsites should also be recorded; for example, whether marsh, riparian, or upland vegetation occurs at a particular location. A broad vegetation survey has already been conducted for all basins at the site, as well as a more detailed transect and plot method in basin 3. Ideally, more detailed vegetation sampling should be done in the other four basins before native plants are introduced into them. Also, soil characteristics – including compaction, depth, salinity, moisture, infiltration, and soil type – should be measured. Several of these measurements have already been taken, but the sample sizes were very low (two measurements inside and outside each basin), and more samples should be taken for greater accuracy of the results. Soil characteristics are extremely important in determining whether certain plants will thrive or be incapable of growing at a site. For gumplant, soil moisture and infiltration rates are very important in determining whether a location is ideal for growth; if measurements are too generalized or inaccurate, much time and money could be wasted by planting gumplant in a location that is too wet for its survival. Also, soil salinity is very good to know, as many plants cannot survive in saline soils; gumplant, however, can. (Hickman, 1993)

Monitoring after introducing gumplant into a site should be conducted in the first year after introduction and continue for at least 5 years in order to get a sense of whether its restoration was successful or not. Five years should envelop both 'forb' and 'non-forb' years, so the recorded establishment would be a measure of the success of the project and not solely a result of climate. Monitoring should be conducted during late summer, when gumplant is in full bloom (Hickman, 1993). Monitoring methods should include percent cover in an area, as well as whether viable seeds are being produced. If a given population, isolated from other populations of gumplant, is small, it may be most feasible and informative to count the total number of individuals present, taking note of whether they are seedlings or mature plants. If a population is larger, counting individuals can be tedious and time-consuming, so estimating the size of the overall area in which gumplant is dominant may be the best method of getting percent cover. If gumplant was introduced into an area, and no seeds germinated or seedlings survived, additional and more in-depth soil monitoring should be conducted in an effort to determine the reason(s) why gumplant was unable to survive. This will help in determining what other species would be ideal for the site instead of gumplant, assuming that conditions are not harsh enough to inhibit all plant growth.

The biggest foreseeable problem in this restoration plan is the uncertainty in soil measurements of moisture and infiltration. The basins are large enough that only taking 2 or 4 of these measurements within them is not enough to represent the range of moisture and heterogeneity of the entire basin, including the upland portion. Gumplant, like many other native plant species, requires a specific soil moisture range (in its case, very low moisture levels) for growth (The Calflora Database, 2009). It would be worth the time spent to conduct more in-depth and accurate measurements of soil characteristics. If a microsite that was previously deemed suitable for gumplant habitat is found to be too wet, it should simply be abandoned for another, drier site. This is much easier than attempting to alter the soil itself, a very expensive and often impossible feat. Other expected problems include competition from natives and exotics, as well as allelopathic chemicals left over from exotics such as mustard.

The uncertainties in this plan include the exact seeding density that would be best for a given site as well as the frequencies of tolerable grazing and fire. A number of restoration projects in the Central Valley have used gumplant as part of a native forb mixture, but seeding densities are usually not published, as gumplant was not one of the focal species of the project. It may be useful to contact several researchers or project managers to obtain the exact seeding densities of gumplant that were used, and whether gumplant restoration was successful. Future research is needed in order to determine the ideal frequencies and intensities of grazing and fire on gumplant, specifically the gumplant species native to the Central Valley, *Grindelia camporum*. Also, it would be interesting to see the results of research that tested gumplant's salt tolerance range; just how salty can soils be that foster gumplant's growth and survival?

G. camporum has previously been studied as a potential inhibitor of the invasive *Centaurea solstitialis*, yellow star thistle, in grassland restoration. Since *C. solstitialis* is a late-season deep-rooting annual, it was thought that the functionally similar *G. camporum*, a late-season deep-rooting perennial, would be similar enough to occupy the niche that the weedy star thistle normally occupies in grasslands and grassland restoration. Unfortunately, *Grindelia* failed to establish for unknown reasons (Stephen L. Young, 2008). As this is an intriguing area of research, it may be beneficial to try this experiment again with different methods or conditions in an effort to yield results that would help in yellow star thistle eradication.

This restoration plan could answer some of these questions – reaction to different grazing and fire regimes, site-specific range of salt tolerance – but the results would not be widely applicable to regions with different soil types and climates. In order to facilitate research that may be conducted on how gumplant is affected by different management regimes, control populations of gumplant should be maintained that are not subjected to any active management, including grazing and fire.

Revised plan

Taking into account the whole spectrum of individual goals for this project, the class was able to formulate one general restoration and management plan that satisfied virtually all goals. Certain areas close to water will be set aside for riparian plant communities and the animals which live in them. Upland areas which are drier will be restored with a mixture of native grasses, forbs, and several small woody species. After considering other goals for different species and ecosystem services, my management plan must be somewhat revised.

It may benefit some of the native grasses to be planted in stands without gumplant so that weeds can be managed by broadleaf herbicides, which could not be used if gumplant was in the vicinity. The diversity of native grass stands will be reduced without gumplant and other forbs, but that will be counteracted by their increased competitiveness.

Also, there is a possibility that the edge of basin 3 or 4 may be restored with a small riparian vegetation community. This would inhibit the establishment of gumplant due to shading from the woody riparian species, so gumplant should not be planted in areas that are designated to be riparian. This will reduce the total area in which gumplant can be planted, but this reduction is small when considering the size of the whole site.

In terms of burning and grazing, gumplant is very compatible with the goals for other species. Most exotics need to be removed through burning or grazing sometime in the spring; gumplant could tolerate these spring disturbances. Burning and grazing later in the year to enhance the growth of native grasses could also be tolerated by gumplant. This is a key win-win situation; it is very difficult to mow or burn around patches of vegetation that are not tolerant of mowing or burning.

The goal of establishing a grassland-forbland mixture is compatible with, and even requires, gumplant's establishment. Having a mixed vegetation stand will enhance the area's ecological diversity. Considering these revisions and goal compatibilities, this revised plan has more win-win situations than tradeoffs.

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Exotic plant species

Exotic woody species

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ENH 160 – Project Part A

4 June 2009

Himalayan Blackberry – Part 1

GOAL

The goal of this project is to eliminate or drastically reduce the occurrence of Himalayan blackberry to allow for the reestablishment of riparian vegetation.

Native to Western Europe, Himalayan blackberry (*Rubus discolor*) was first introduced to the United States in 1885 as a cultivated crop for its succulent berries. By 1945 it had become a major problem in the Pacific Northwest, colonizing moist, disturbed sites and riparian areas. Himalayan blackberry has an invasiveness ranking of 77 out of 100, based on its ecological impact, biological characteristics and dispersal ability, ecological amplitude and distribution, and feasibility of control, meaning it is a species of particular concern in California (Lapina 2005). Essentially, this means that it poses a significant threat to existing, “natural” ecosystems. Populations spread rapidly and vigorously by a variety of methods and can shade out and severely reduce native plant diversity. Dense thickets resulting from this aggressive spread can take over streams, impeding the movement of large mammals and presenting an increased fire hazard (Weihe and Ness 2005). While the fruit and buds can be a dietary component for several types of native animals such as bears, birds, squirrels, deer, rabbits, and coyote, it is an inferior substitute for a diverse and multi-functional natural system (Soll 2004, Weihe and Ness 2005). Management of this species is a key issue which needs to be addressed in order for the restoration of riparian vegetation to succeed.

LITERATURE REVIEW

MORPHOLOGY OF HIMALAYAN BLACKBERRY, COMMERCIAL USES

There are eleven other species of blackberry native to California and five other non-native related species (Hoshovsky 2000). Himalayan blackberry can be distinguished by its characteristic cluster of five leaflets, strongly angled stems, and spines with wide bases. Himalayan blackberry has been shown to hybridize readily with a number of these species, decreasing the genetic integrity of native varieties (Weihe and Nees 2005).

Himalayan blackberry will grow very well in infertile soils and tolerate a wide range of soil pH as long as there is adequate soil moisture, or more than 30 inches of rainfall annually (Hoshovsky 2000). In general, seedlings will not germinate in shaded areas such as blackberry thickets or forest understory, however they will readily colonize open areas resulting from a significant disturbance. Viability of seedlings of the Himalayan blackberry may increase after passing through the digestive system of animals. Generally, seeds require a warm stratification for ninety days at 68-86 degrees, followed by cold stratification between 36-41 degrees, conditions consistent with the summer and winter seasons (Hoshovsky 2000). Seedlings are generally slow growing and highly susceptible to shade, and seeds can remain dormant in the soil for several years.

Dispersal of Himalayan blackberry occurs in a variety of ways. Seeds can be dispersed by birds and mammals or flowing bodies of water. The plant also vegetatively spreads through rooting of the cane apices, lateral root suckering, and rooting of slash

(Weihe and Nees 2005). Individual canes will elongate to lengths of up to forty centimeters before arching over to trail on the ground (Soll 2004). Up to ninety-six percent of canes will develop daughter plants from shoot apices (Hoshovsky 2000). Adventitious shoots can emerge from roots at a depth of 45 centimeters. In addition, root and cane cuttings from mechanical removal, if left unattended, may root and form additional thickets.

Berries of the plant are harvested for commercial sale in Oregon and Washington but have widely escaped cultivation. Since it is so widespread the plant often provides fruit to independent parties on a community level as well. Berries are commonly consumed by birds, coyote, red fox, squirrel, and black bear. Buds, stems, and leaves of the plants are consumed by deer, beaver, porcupine, elk, and rabbits (Weihe and Nees 2005).

EFFECTS ON NATURAL PROCESSES

Because of its rapid growth pattern and dense formation of thickets, Himalayan blackberry majorly alters native community structure, exterminating native species, reducing biodiversity, and creating monotypic stands of exotic vegetation (Lapina 2005). While individual canes may only live 2-3 years, cane density can reach up to 525 canes per square meter (Soll 2004). A single cane can produce a five meter thicket during this time period. Large quantities of hard dry litter will build up in older thickets and can present a significant fire hazard when near buildings. Dense thickets may impede the movement of large mammals and limit their access to water. They will severely reduce nesting and foraging sites and impede access of waterfowl to waterways, possibly leading to the removal of existing native populations (Lapina 2005). These thickets may also reduce available pastureland for grazing (Hoshovsky 2000).

ERADICATION AND MANAGEMENT OPTIONS

Himalayan blackberry is difficult to eradicate because of its extensive root system, which can reach depths of 35 inches (Soll 2004). Flow of carbohydrates and water will continue between the interconnected plants, allowing them to establish at significant distances from their water source. Management is also affected by the sensitivity of the habitats it has invaded (Weihe and Nees 2005). Ecosystems predominated by western hardwood, Hemlock-Sitka spruce, Maple-beech-birch and oak, loblolly and shortleaf pine and white, red and jack pine are particularly sensitive to Himalayan blackberry invasion.

Because Himalayan blackberry is still utilized for commercial purposes, introduction of a biological control is considered unfavorable. Grazing by horses, cattle, or goats may contain the spread of thickets, but will not reduce or eliminate existing established thickets (Hoshovsky 2000). Removal of thickets requires two processes: removal of above ground vegetation and removal or root systems. Mechanical removal - such as mowing and hand pruning - or prescribed burning are effective means of removing above ground vegetation. Slash resulting from mechanical or hand removal may be used as a mulch or cover for wildlife if no seeds have been produced, but it can also be burned. One advantage of this method is that it will not stimulate sucker formation, however it is often labor intensive and machinery can be costly. Most mechanical removal will cost anywhere from $250-$500 per acre, and most machinery cannot operate on slopes greater than thirty degrees. This cost will tend to increase with the steepness of the slope and the density of the vegetation to be removed. Burning is generally more effective on slopes, however consideration needs to be given to the provision of fuel so the fire will burn relatively evenly over the desired area. This process generally requires a significant amount of preparation, often including the application of herbicides before and after the burn.

Root removal can be accomplished in several ways: grubbing/digging out root systems, repeated removal of above-ground vegetation, treatment of freshly cut stumps with herbicide, treatment of new cane growth with herbicide, or treatment of mature canes with herbicide (Soll 2004). Hand removal of roots has proven to be effective, but can be expensive and labor intensive. Younger plants are generally removed first by hand pulling or hand hoeing to remove the root crown. More intensive grubbing is required with mature plants after the canes have been removed. Care must be taken to remove the entire root crown, as broken off pieces will resprout. Because of the intensity of labor, this technique is usually most suitable for smaller infestations unless a large work force is available. Removal of canes alone will be insufficient to control infestations unless repeated multiple times, or until the roots exhaust their stores of food. If this is the preferred method of removal cuttings should be conducted when the plants are in flower. This method does have a possibility of soil compaction and detrimental effects on remaining native species due to trampling.

Chemical application is another method used to control Himalayan blackberry. Some herbicides, such as Garlon 3A, Roundup, and Crossbow, are considered to be more effective than others (Picloram), which stimulate the formation of adventitious shoots (Tirmenstein 1989, Soll 2004). Care should also be taken in riparian areas or near streams, because herbicides may leach into the water and be dispersed over a large area

(Soll 2004). Generally, foliage spraying should be conducted during a dry spell to prevent herbicides from leaching into the soil. Foliage spraying is also more effective in the summer than in the winter (Hoshovsky 2005).

After thicket removal has occurred, reestablishment may be prevented by planting trees or shrubs that will rapidly grow and shade out seedlings (Weihe and Nees 2005). Some management procedures require multiple applications or projects. Even with preventative measures in place, resprouting is still likely, and the site should be regularly monitored.

Part 2

GOALS

Short term: Complete removal of all existing stands of Himalayan blackberry and establishment of a management plan to prevent future reoccurrences, allowing for the introduction and successful establishment of native plants species. This will be conducted on a stand by stand basis.

Long Term: Monitoring and control of resprouting and spread of stands. If infestations along the waterway are controlled it is unlikely that seeds would be dispersed by water. If removal of existing stands is successful clonal propagation will be eliminated or significantly reduced. With the loss of this food source and the lack of other blackberry stands in nearby areas bird and mammal dispersal is significantly reduced. There are no nearby populations which would provide a significant source of seed introduction to the site, as it is mostly surrounded by agricultural land.

MANAGEMENT PLANS

There are two main restoration plans, each geared toward a specific infestation on the site. The first restoration plan addresses the infestation around the lower pond closest to the road while the second addresses the much larger infestation in Basin 5.

The first restoration plan is to use hand removal to take out both above and below ground structures. Even though this is the most expensive option there are several reasons for this choice. For above ground removal, the proximity to water and slope of the banks removes the possibility of mechanical mowing. Since the soil around the stream is so saturated there would also be a risk of detrimental soil compaction. Prescribed burning would remove the above ground vegetation, but since canes have grown into the crowns of the trees it is likely that any burning would kill the desired woody species as well as the blackberry. Debris such as ash from the fire would likely contaminate the stream and parts of Putah Creek, and the loss of these deep rooted species along the banks could increase erosion in subsequent years. Hand removal is best for above ground removal because it offers the option of taking out dead canes as well as live canes, significantly reducing the fire hazard posed to the other woody species in the same area with a minimum amount of soil compaction. Grazing is another option, but goats are the most effective control animal and they prefer not to feed near water (sheep merely eat the foliage). Options for removal or below ground vegetation are hand removal or application of pesticides. Proximity to water and saturation of the soil could lead to contamination of the water if pesticides are used. Grasses and/or other desirable species should be planted after initial removal has occurred to minimize the possibility of seed germination. Monitoring should be conducted to remove all other adventitious shoots, which are not affected by lack of light.

The second restoration plan uses grazing or fire to remove above ground vegetation and pesticide application for below ground removal. Since this is such as large infestation hand removal and mowing are ruled out simply by cost and effort required. Grazing and prescribed burning are the only two available options, but each has its drawbacks. Grazing with goats will remove almost all of the above ground vegetation as well as other invasives in the same area, such as Milk thistle, however they will not eat any dead plant material since it is not as palatable (ASI 2007). Dead, dry cane material poses the greatest fire risk, and Basin 5 is the closest to the aquaculture facility. Prescribed burning would solve this problem, however it is a hassle to obtain permits, puts the aquaculture facility at risk, and decreases air quality. If grazing is the method of choice additional measures must be implemented to remove this fire risk. After the above ground vegetation is removed a basal application of herbicide such as 2, 4-D or Triclopyr ester should be conducted (Tirmenstein 1989). A spring application of Crossbow to the wounded base of the shoot is likely to be most effective, since goats prefer to eat the tender, new growth of the plants (ASI 2007). This would involve one to three weeks of grazing followed by a broadcast herbicide application. Again, planting of desired species should occur after the initial removal and spraying, with subsequent monitoring to remove adventitious shoots.

There are a multitude of research opportunities associated with this restoration plan. Experimenting with the timing of grazing or controlled burns is one option. The effect of burning and grazing on other invasives in the same area and their effects on native target species (e.g. resprouting from dormant seed, occurrence other invasives, etc.) is another. It would also be possible to experiment with different types of pesticides and pesticide applications in Basin 5 using test plots of defoliated and still vegetative blackberry canes. While there are some pesticides that are recommended for Himalayan blackberry control it is unknown which is best for use under a given set of conditions. Experiments could be conducted into the effects of pesticides on native target species or multiple applications at various times of the year vs. at the same time every year. Data from these experiments could potentially increase the success rates of restoration projects dealing with infestation of Himalayan blackberry.

Both of these restoration plans would ideally include a 3-7 year monitoring plan after initial removal to check for suckering in Basin 5 and overall regrowth. Monitoring in this case constitutes a thorough scouring of the cleared and treated site for sprouting every season, especially spring and fall. Success of the restoration project will be determined based on regrowth after the selected monitoring has been completed. Only complete removal of all canes will constitute a success. The maximum amount of time seeds are viable in the soil is unknown, however seven years (approximately) is the amount of time necessary to ensure that the food source stored in the roots has been depleted due to cutting, grazing, or fire (Tirmenstein 1989). For restoration plan 1 three year monitoring may be all that is necessary, however Basin 5 will likely require the full seven years of monitoring. Either restoration plan will likely require a secondary removal project or period of grazing. This should be determined based on percentage of sprouting. Spot treatment with herbicide would be more effective than grazing for a small percentage of resprouting, with grazing being favored if there is a large percentage of resprouting.

SUMMARY

1st Restoration Plan: Use hand removal of above and below ground structures.

2nd Restoration Plan: Use grazing or burning for removal of above ground vegetation, pesticide application for below ground removal.

Minor infestations in other basins should be dealt with using the first restoration plan.

One additional consideration to address is the possibility of the stream channel being moved to create a larger riparian area. If this occurs disturbed areas should be continuously monitored for Himalayan blackberry seedlings, since they readily colonize wet, disturbed sites. If any seedlings are found they should be pulled immediately before the roots have a chance to establish.

There are several knowledge gaps associated with the removal of Himalayan blackberry that existing research cannot account for. It is unknown whether or not overgrazing will create a disturbance sufficient enough for colonization by Himalayan blackberry. Also, since many species use this plant as a food source it could be important to consider how these species will replace the loss of this food source. It is possible that some median could be reached by planting native blackberry, but these have similar growth habits and readily hybridize, so they may possibly become more invasive. Planting other riparian species, such as sedges, would be more desirable and may also provide an adequate substitute if combined with upland grasses and eventually forbs.

Part 3

Overall, the management of Himalayan blackberry infestations on site fit nicely into a collective management plans for other invasive species. An early spring grazing, prescribed burn, or pesticide application will affect the greatest number of invasives, such as ripgut, milk thistle, pepperweed, and mustards, while doing the least amount of damage to natives. This is especially effective for Basin 5, where you have so many different exotics. One tradeoff will be managing for invasive species such as ryegrass and star thistle, which prefer dry season burning or grazing. Another positive for co-management is that it may be possible to use the same pesticide for almost all applications. Roundup and 2,4-D seem to negatively affect the blackberry and milk thistle as well as star thistle, which was not controlled as well as the other exotics by early spring timing of burning, mowing, or grazing. These chemicals do affect forbs, but planting of these species can be stalled for several years until infestations of exotics are dealt with. It would be feasible to work Himalayan blackberry management into the integrated project with few tradeoffs.

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Exotic grass species

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04 June 2009

Control of Ripgut (*Bromus diandrus*)

Goal

Enhance ecological resistance and removal of Ripgut brome through cultural, biological and chemical techniques, by using specific herbicides, hand removal and/or prescribed burns. Removal should consist of getting rid of present Ripgut, reducing the seed-bank and preventing it from re-establishing. After the removal, keep monitoring the area for a few years in case new outbreaks appear. Monitoring for the first couple of years will need to occur at least twice a year since seedlings might re-sprout. After assuring that the seed bank is significantly reduced, monitoring can occur every year or every other year.

Introduction

Ripgut is an annual grass native to Eurasia. It is believed that it became widely established in California by the late 1800s (Fletcher, 105). Nowadays it is found in other places especially of Mediterranean climate, such as Australia. In North America, this grass mainly extends from California to British Columbia, and it is placed under the noxious weed list of United States.

This species of brome is generally found in disturbed fields, grasslands, and roadsides below 6,600 ft (Tarbell). It can establish over a wide range of soil moisture, and the presence of mulch and crop residue, favors its buildup.

Ripgut can only reproduce by seed, and each plant produces approximately 1000 of them. Seeds can spread through wind, soil movement, water and/or by clinging to animals and humans. Germination occurs between November and April, and seeds have longevity of up to 5 years (Fletcher, 104).

Ripgut has become a very detestable plant since it has contributed to the modification of water and soil characteristics, which makes the environment suitable for other annual grasses. Seedlings of perennial grasses get outcompeted and shaded out by this tall invasive species, altering the cover area for native species. (BLM)

Ripgut can outcompete native oak seedlings for water in soil; by germinating early in the season, developing a root system in a faster period of time, and having a larger cover area (Fletcher, 104). Ripgut is also very problematic in agricultural lands since it reduces the yield of cereal crops due to its competitiveness for water and nutrients. It also affects livestock by contaminating wool through its seeds; and because of its scabrous edged blades, it can damage feet, eyes, mouth and intestines of animals and humans. (Griffith)

Laws and Policies

Bromus diandrus falls under the category of noxious weeds in United States, which stands for “any living stage of a parasitic or other plant of a kind which is of foreign origin… and can directly injure crops, or other useful plants, livestock, poultry or other interests of agriculture…” (Wildlife Law).

According to the Federal Noxious Weed Act, the general management of unwanted plants should meet the following duties by Federal Agencies:

(Amendment to the Federal Noxious Weed Act)

- Assign an adequately trained person to coordinate the management program
- Fund the project
- Implement agreements with State agencies regarding management
- Establish an integrated management system to control undesirable species, and designate a time frame
- Projects could take place in private or federal lands.

In California, some of the general duties that landowners, harvesters, inspectors… must take in account in order to destroy weeds are the following:

(The Noxious Weeds Act)

- "Each occupant of land, or, if the land is unoccupied, the owner thereof… shall destroy all noxious weeds and noxious weed seeds growing or located on the land as often as may be necessary to prevent the growth, ripening and scattering of weeds or weed seeds."
- Equipment must be cleaned in between and when leaving to another land, so no dispersal or contamination occurs
- Prescribed burns and safe herbicides are allowed, but must be done by trained people and follow regulations
- Must have a list of all noxious weeds in the land

<u>Studies</u>

- Cheeseboro Canyon in Santa Monica Mountains, CA: A burned area had 96% fewer viable seeds of Ripgut, leading to replacement of forbs and native perennials. *Nassella pulchra* and *Artemisia californica* showed to be great candidates for introduction after burning. (Moyes, 659)

- Yuba city: First-year prescribed burn followed by a second-year clopyralid treatment provided a consistently good control of yellow starthistle, medusahead and ripgut. (DiTomaso)

- Australia: Seeds germinating under favorable environmental conditions (including seeds closer to top soil) will germinate in about 27 days with a 95% chance of success. (Harradine)

- •Morocco: Deep tillage reduced seed bank by 96.6% for seeds buried deep in soil and 66.7% for shallow buried. Seeds survive < 3 yrs at deep soil. Disc plough reduced brome population and seed bank significantly. (Hamal)

Funding

The main source of funding should come from state and governmental agencies, since this weed causes so many consequences for the environment and economy. Ripgut takes up high amounts of nutrients, reduces yield of crops and decreases the quality of livestock. Federal agencies, volunteers and schools can work together in various levels – from hand removal, mowing, prescribed burns and herbicide applications – to remove this invasive species.

Davis is surrounded by agricultural land and by having Ripgut present in those sites or in nearby areas, it can cause great economical loss in relation to livestock and cereal crops. By proposing that idea, it may allow more agencies to provide funding since it would be affecting an important part of our economy. For example, the Bureau of Land Management could be an option for funding, especially since Ripgut is listed under the Noxious Weed List. BLM states that their "highest priorities is to promote ecosystem health and one of the greatest obstacles to achieving this goal is the rapid expansion of weeds across public lands." BLM could also be a funding candidate since their budget has increased slightly in the past few years. (BLM-Invasive Species)

<u>Factors affecting goal</u>

- Grazing can only be an option if Ripgut is still in the vegetative stage with soft and wide basal blades, since later in the season once it enters the reproductive stage –late March, April and few months after; blades become scabrous, and dangerous for consumption. (Stromberg)
- Ripgut becomes very dry and flammable during the summer (or dry seasons), causing increase in wildfires, and thus increase in grasslands (Cal-IPC).
- Funding and involvement of agencies.
- Seed bank can remain in the soil for up to 5 years.
- Biological control agents such as nematodes, insects, and pathogenic fungi could be used to remove Ripgut, but they may also attack other species such as cereal crops. (Griffiths, 11)

<u>Restoration Management Options</u>

- Disease and Insect Control. These tend to have a bigger impact on plants that are best competitors for resources (exotic annuals), rather than stressed plants, which usually tend to be the natives. (Griffiths, 11)

- Controlled traffic systems. Set up an appropriate timing for herbicide applications, before seed set. (Griffiths, 11)

- Commonly used herbicides for Ripgut growing near cereal crops are: Midas®, Monza™, Atlantis® (Griffiths, 8), Clopyralid (DiTomaso) and Osprey® *mesosulfuron* (Canevari)

- Hand removal. The root system of Ripgut tends to spread horizontally so removal by hand is easy if quantity is not too much. Removal must be done before seeds are ripe, when seeds are hanging and a milky substance is still present in the plant tissue. (Fletcher, 104)

- Mow or weed whip larger populations. Cut grass to about 2 inches, so the bolting crown is completely removed. Mowing should be done from late March to April before seeds mature. (Fletcher, 104)

- Prescribed burns.

Ripgut has a variety of management methods for its removal and control, but finding the appropriate one for a specific location may take much longer, and use up more funds. Experimenting at first in a small part of the area is a good step.

Goal and management plan for Ripgut (*Bromus diandrus*)

Short Term	- Large scale. Identify all species in the area being restored, native and invasive. Important to know which species are present to create the best restoration management plan. Some plants are important for pollination, forage, mating, etc, and the least disturbance to those species would be a priority. - Small and large scale. Control the population of Ripgut at the site. Try to reduce the amount of these species by tillage (so seeds are placed closer to topsoil), mowing or hand pulling; or control its spread until a long-term management is applied. - Large scale. Monitor the area for new out-breaks of Ripgut. Control and monitoring go together to have a better idea of the area being restored and cost.
Long Term	- Large scale. Remove the species and reduce the seed bank. Burns and herbicide applications might be the best options for the removal of this species, since it will destroy almost 100% of the seed bank and plant tissue. This is supposing seeds are exposed, or near the soil surface. Seeds buried deeper in the soil might not be affected, but by just being buried deeper, they have a lower chance of germination rate. Problems may occur such as disturbance to other species, for example native perennials, giant garter snake, western pond turtle, ground nesting species, and others. - Small and large scale. Monitoring and controlling the area for the first 5 years, to check if re-introduction or new seedlings begin to emerge since longevity of seeds is up to 5 years. Depending on site some areas might be more successful for restoration than others (for example few of the basins in the Putah Creek Reserve) so focusing more on those is also important.

Restoration Plan

Short Term

- Hand Removal – Small scale. Better if done in areas that Ripgut is not dominant. Preferred removal before seeds are fully mature, from late March to April. According to the basins, hand removal could be done on the edges, so each population is more separated from one another.
- Mowing and/or Weed Whip – Large scale. Leave up to 2 inches above ground so crown is completely removed. Dates are same as hand removal. Depending on the machinery being used, it might cause compaction. For some of the basins it might be very hard to introduce equipment because of shrubs and soil, for example basin 1 which has a wetland type of environment, and basin 5, which is covered in shrubs and thistle. Weed whip might be a good option for these two basins.
- Deep tillage – Small to large scale. Can reduce the seed bank up to 96.6%. Tillage might have to be done by hand depending on vegetation and terrain. Basin 2, 3 and 4 could use tillage since their inner basins vary in compaction and the terrain is easy to move through. This method could be used before performing a burn and/or herbicide application since it would cause part of the seed bank to be exposed.
- Herbicide Application – Small scale. Very effective but usually not selective. Not only Ripgut would be removed, but almost every other plant in the treatment location. After herbicide applications there must be a following management plan if not Ripgut seedlings may reappear from the seed bank, which will again outcompete the natives.

Long Term

- Herbicide Application – Large scale. Examples of herbicides mainly used for Ripgut control are: Clopyralid and Osprey® *mesosulfuron*. It is best if other treatments are being used as well, such as prescribed burns and reintroduction of natives (by seeds, seedlings, cuttings). This restoration plan is not be preferred since animals and water bodies belong to the environment of the reserve, but if too many invasive species are present it might have to be taken in consideration. Detriments such as runoff, pollution, disturbance to ground nesting species and native perennials removal may occur.
- Prescribed burns – Small to Large scale. Not all 5 basins need burns. Fire can reduce up to 96% of viable seeds. If using herbicides, it is best to apply after a burn, especially Clopyralid (DiTomaso), since it reduces Star Thistle, Medusahead and Ripgut. Clopyralid seems like it would be the best option since it would target two of the exotic species present in most basins, Star Thistle and Ripgut.

Potential Problems

- One of the major problems would be funding. Even though this plant has various reasons why it would be a potential candidate for funding; such as outcompeting the natives, changing soil characteristics, rapid spread, decrease in cereal crop yield… it is not the only invasive in the site. It is important to know which invasive species are causing the most detriments, and also how large is budget.

- The period of seed maturation is not that long, so timing is important if hand pulling or mowing. Late March and April are the ideal times for performing these removal techniques, but environmental factors such as rainfall or drought could delay the plans. Machinery might not be able to enter if soil is too moist. This could even cause postponement until next year, or application of other treatments such as herbicides.

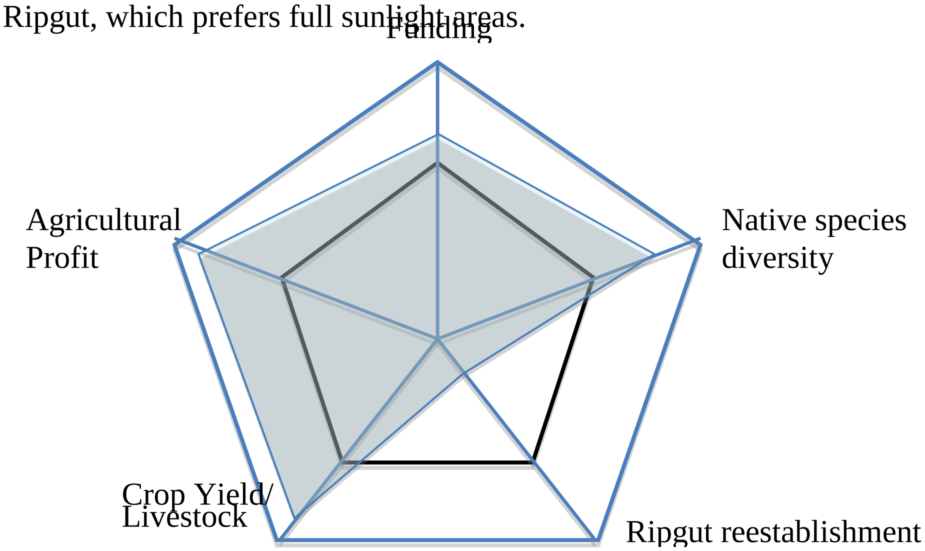
Research Questions:

- Are there any threatened or endangered species located in the site?
- Are there any specific regulations for the site that may affect restoration plans such as, herbicide applications, prescribed burns, use of machinery (e.g. Mowers, tractors?
- Once Ripgut is removed, will the natives increase in population? Do we need to reintroduce the natives? Will it be better to plant by seed, seedling or cutting? Does it depend on the species?

Some of these questions can be answered by the managers of the site, regarding regulations, restrictions etc. For the other question (native reintroduction), the best option will be to set up plots comparing treated and control to see if any success occurs before applying it at a large-scale. This will help choose the best restoration methods for the different basins.

Ripgut does not provide any beneficial factors to the Putah Creek Reserve, so removal is the only option. Most invasive species have a similar growth season, and removal coincides almost exactly to as of Ripgut's. So far the best management plan for most exotic annuals in the site is mowing or grazing (except for Ripgut) during March and April, when species are still in vegetative stage. Burns seem to work with all invasive species, but since native perennials are present it may cause drawbacks to their reintroduction to the site. Restoration methods for most other exotics in the reserve will work with Ripgut as long as it is done in between those two months.

The Giant garter snake and the western pond turtle do not seem to be affected by this grass since their habitat consists of being near water bodies. Ripgut is usually not found in areas like that since it get outcompeted by native wetland species such as Cattail or by riparian species such as oaks which provide shading and in result an unsuitable habitat for Ripgut, which prefers full sunlight areas.



If funding is sufficient for restoring the site to its natural state, benefits in different areas will be seen in short and long term in the reserve as well as in other fields. Farms located near the reserve may increase their cereal crop yield and livestock quality since wind, animals and humans are not causing the dispersal of seeds – this is supposing the main source of Ripgut entering the agricultural land is from the Putah Creek reserve and farmers are also implementing methods for weed removal.

Once Ripgut is removed from the site and constant monitoring for the first 5 years is done, reestablishment of *Bromus diandrus* will have a very low chance of success since by that time, most native perennials will be fully grown and established.

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Italian ryegrass (*Lolium multiflorum*)

DJ Eastburn

Part I

Background & Justification

Overall goal is to facilitate a natural succession to a desired state or climax community. Through utilizing herbicides, grazing and fire we hope to select for a manageable Italian ryegrass community as the initial seral stage. A strict adherence to the management prescription should lead to the projected state of shrub/tree dominated community minus non-native invasives. In the event our goals are not attained, the effort will deliver insight to the viability of using *L. multiflorum* as community control species. Initially, the California exotic annual Italian ryegrass (*Lolium multiflorum*) was introduced to many different ecosystems around world for various agricultural benefits (e.g. probably introduced to California for Spanish livestock) (Terrel 1968). *L. multiflorum* is a highly nutritious crop for range foraging livestock (Potter et al. 2009). The Italian ryegrass has become a major component in the exotic dominated California annual grasslands (Barbour et al. 2007; Smoliak et al. 1981). Ryegrass has controversially been utilized for reducing erosion of recently burned areas of the western United States (Hafenrichter 1968).

Although *L. multiflorum* is very effective at quickly reducing the risk of soil erosion; the grass may prevent the normal succession of a degraded habitat to a climax community such as valley oak (*Quercus lobata*) woodland (Hafenrichter et al 1968; Hobbs and Mooney1986; DiTomaso and Healy2007). However, the current body of literature provides contrasting views on whether *L. multiflorum* aids or inhibits the succession of a given disturbed site. It is believed that by creating dense mats of dry residual plant matter, the Italian ryegrass can make it very difficult for seedlings of other species to establish, especially shade tolerant species (e.g. Kolb et al. 2002; Hobbs and Mooney 1986; Halpern et al.1990). The potential risks of allowing *L. multiflorum* to persist at a site are associated with its abilities to quickly invade nearby area. Even historically invasive resistant sites that possess highly specific conditions, which only endemic species typically tolerate, are vulnerable to invasion from Italian ryegrass. This strength is exampled by the signs of early invasion into alkali grasslands (Veblen and Young 2009). However, the inability of *L. multiflorum* to cope with intense grazing pressure coupled with a resistance to multiple herbicides and short lived seed bank are attributes showing promise in utilizing *L. multiflorum* as a restoration tool to facilitate succession to a chaparral or woodland climax community from that of a highly invaded state pending evidence that *L. multiflorum* can be controlled and doesn't prevent the establishment of woody species.

The ability to dominant a well drained site and be selected for by a glyphosate resistance may allow the opportunity to control a restoration sites plant community by initially creating a pseudo-monoculture of Italian ryegrass (Isik et al. 2009; Gulman 1979; Jasieniuk et al. 2008). Even though the rye grass has many dominant and invasive traits, it is easily probable that it may be managed through sensitivities to shade, fire and grazing. Thus giving rise to becoming a possibly critical player in facilitating the succession of disturbed or degraded states to climax communities like valley oak woodlands. The once native species dominated rangelands of California are the subject of increasing land management agency attention. The possible information to be gained from experimentally employing an Italian ryegrass tooled restoration of barren or poor quality range into a native like, multi-layered habitat would be valuable to future restoration projects.

The Italian ryegrass grows in a wide range of soils, however, it requires medium to high fertility to persist (Ditomaso and Healy 2007). The ryegrass grows best in highly fertile and well drained soils (Ditomaso and Healy 2007). If established the ryegrass can tolerate periods of flooding, which allows the rye grass to pose a significant threat to our riparian edge habitat(Ditomaso and Healy 2007).. The species is widely distributed throughout California and North America (USDA). However, *L. multiflorum* is shade intolerant and does not thrive during long periods of drought (Ditomaso and Healy 2007).. Although the species produces an abundant amount of seed, that can germinate year round with optimal moisture conditions, the seed bank is generally short-lived (approximately less than 5yrs) (Ditomaso and Healy 2007).. The Italian ryegrass generally tolerates trampling, mowing and grazing, yet will be very sensitive to prolonged/intense grazing after a dry season fire (Hervey 1949; Ditomaso and Healy 2007). The ability to quickly colonize and establish dense stands has lead to ryegrass invasions of many California grasslands. However, these very attributes have made it a cost effective choice, compared to native seeding of species like *Leymus triticoides*, in reducing erosion post fire.

While *L .multiflorum* has only been used as a restoration tool purposefully in post fire erosion control, the grass specie possesses many qualities that could allow employing its use in restoration strategy. Utilizing this species in weed suppression has proven to be useful in organic crop systems of the Mediterranean Basin (Isik et al. 2009).

The ability of *L. multiflorum* to dominate habitat through life history strategy and glyphosate resistance coupled with the high nutritional value provides viability to the idea of using *L. multiflorum* as a management tool in range restoration. Maintaining a high level of restoration site productivity will be a valuable aspect in gaining adoption of our restoration strategy among land managers and bean counters alike. Especially if productivity maintains progress towards restoration goals and reduces management budget strain by allowing for costs to be offset by grazing revenues from site grazing use or permits.

Using glyphosate resistance and *L. multiflorum's* dominating traits in controlling a degraded/invaded habitat could be less management intensive than other restoration strategies like early spring mowing, transplanting and tilling (Isik et al. 2009). However, in order for the Italian ryegrass community to be competitively exclusive, a fertile site rich in nitrogen, phosphorous and other nutrients is required for persistence (Smoliak et al. 1981). The high fertility needs of Italian ryegrass and other annual exotic grasses in California is common (Barbour et al. 1993). Fertile and non-fertile sites coincide with exotic invaded and native relic communities in California (Barbour et al 1993). The prior attributes makes the Italian ryegrass tool a good candidate for agricultural site restoration. Although it is empirically unknown whether annual grassland composed of wild oat (*Avena spp*.), soft chess (*Broma spp*.) and italian ryegrass (*Lolium multiflorum)* can significantly restrict poor forage quality species like medusa head (*Taeniatherum caput-medusae*) and yellow star thistle (*Centaurea solstitialis*), does not deem the strategy unnecessary for consideration. Conversely, the combination of herbicide application and managed grazing may allow for shrub or tree recruitment necessary to provide canopy and in the case of oak woodlands the development of shady islands of fertility for establishing native perennials.

Any management plan utilizing Italian ryegrass communities as the initial seral stage will require multiple years and intensive management. Since Italian ryegrass is capable of forming dense, dominating communities and being vulnerable to fire and heavy grazing forces at the same time, the need for management prescriptions to be closely followed is essential for restoration success. A thin line exists between *L. multiflorum* regulation by grazing and *L. multiflorum* extirpation by grazing intensely in early spring or high intensity grazing for prolonged periods after fire (Hervey 1949). Due to *L. multiflorum*'s intolerance of shade, the assumed result of site climax will naturally inhibit the species persistence at the restoration site (Terrel 1968). Even in the event of *L. multiflorum* site persistence, an ideally timed controlled burn followed by prolonged, moderately intense grazing could be sufficient in suppressing the species (Hervey 1949).

Part II.

Italian Ryegrass (*Lolium multiflorum*) Removal and Suppression Guide
Cautions before removal or suppression: • Determine extent of invasion compared to other less desirable invasives through extensive vegetation sampling; *L. multiflorum* may not be a problem? • Determine threat of present *L. multiflorum* population becoming source for invasion to nearby habitats • Consider impacts on native plant species of concern (if present) before implementing removal strategy because *L. multiflorum* eradication may also eradicate desired native species. . • Determine desired plant community before employing restoration plan; will the steps to remove *L. multiflorum* inhibit desired plant community results? Will *L. multiflorum* presence not impact the

establishment of desired species (i.e. Baccharis spp. can establish in dense stands of Italian ryegrass)?

Steps of suppression and removal:

- Allow site to build up dry residual plant matter from multiple growing seasons (i.e. cease grazing or mowing) in order for prescribed fire to sufficiently carry
- Plan and implement a prescribed burn to occur during dry season for best results, ideally in fall before first rain.
- Prescribed burn should be followed by moderately intense grazing in the early spring before anthesis, 4 cow/calf pairs per hectare may be adequate in reducing *L. multiflorum* abundance and seed bank.
- Before repeating restoration steps, site vegetation should be monitored and rested for a year to allow any remaining seed bank to germinate. Repeating these steps will likely take advantage of *L. multiflorum's* short lived seed bank and lead to *L. multiflorum* extirpation.
- Highly recommended to establish (seed or transplant) desired species soon after prescribed disturbance in order to avert another invasive filling the vacant *L. multiflorum* niche.

Restoration Goals

The site intended for restoration has a history of mixed land uses (i.e. reindeer pens, wetland fish pools, etc.) coupled with unique patches of habitat that will require a diverse array of management strategies. Our restoration goals are adapted to incorporate the restoration and maintenance of grassland-prairie and oak woodland habitat. The species of interest, *L. multiflorum*, plays a diverse and critical role influencing restoration and management plans of the various habitats. The objective of our project is to develop a mosaic of habitat patches that in turn will support a diverse and stable community of plant and animal fauna. In order to successfully restore and maintain such a diverse community structure, multiple goals focusing on short-term and long term temporal scales must be incorporated into our plan of action, as well as the interim needs of constituent fauna must be considered. Furthermore we anticipate the restoration of prairie-grassland and valley oak woodland in close proximity to a riparian corridor may be the most promising strategy to meet our projected goals.

Our intended goal to create grassland-prairie habitat, in close proximity to the riparian corridor, that possesses a high degree of patchiness will require management regimes varying in space and time. The high degree of patchiness aims to allow refuge, throughout the restoration process, for species dependent on various microhabitats. Some native animals such as giant garter snake, pocket gophers and voles require mixed patches of dense cover provided by grasses like *L. multiflorum* to sustain healthy population levels (Taskey et. al.). In turn higher trophic species like *Buteo swainsoni* and *Elanus leucurus* depend on healthy populations of pocket gophers and California voles. Therefore our aim is to provide a bottom level trophic restoration of grassland-prairie tailored to support an intricate network of species.

In addition to the restoration of grassland-prairie habitat, the development of valley oak woodland may provide critical nesting and foraging habitat for different suite of species connected to riparian corridors. Through the manipulation of disturbance regimes and plant interactions, our goal is to create a successional procession to our intended climax community.

Restoration Plan

The two community types emphasized in our project goals require different restoration prescriptions. In order to fully utilize land near the riparian corridor, our restoration goals include the restoration grassland-prairie because of the important benefits to a suite of wildlife species associated with riparian corridors that depend on grassland/prairie for foraging, nesting, etc. Of all our restoration objectives the grassland/prairie may be restored on the smallest temporal scale. However, in order to maintain the grassland/prairie at the site may require long-term management efforts like continued intervals of prescribed disturbance over long periods of time (Hervey 1949). Furthermore the restoration of grassland/prairie may necessitate the depletion of the extensive non-native seed bank persisting at the site.

We propose that a pseudo- monoculture of *L. multiflorum* and *Leymus triticoides* be the initial species managed for, in the grassland-prairie basins, through glyphosate herbicide application and dry residual plant matter build up (Jasieniuk 2008; Ditomaso and Healy 2007). In the event an herbicide resistant, or unknown vulnerability to herbicide, species like *Lupinus arboreus* is encountered the plant will be manually removed or killed to allow the quick establishment of the suppressive *L. multiflorum* that has been seen in some *Lupinus spp.* conditioned microhabitats (Kolb et al.2002). Although, the *L. multiflorum* is known as an invasive species, it may provide a restoration starting point through the inhibition of other invasive Mediterranean Basin species and other invasive exotic plants (Isik et al.2009). At the point when vegetation monitoring suggests that the *L. multiflorum* is the overwhelmingly dominant community constituent, which may take multiple years, the next step of phase I will commence to a reduction and replacement management strategy. The short-lived seed bank of *L. multiflorum* will be a fundamental weakness exploited during the second step of phase I (Hervey1949; Smoliak et al 1981). The initial method used in step two will employ an early fall controlled burn to reduce the dry residual matter built up from previous years of light to non-grazing regimes. Upon the first fall rains, it is likely many *L. multiflorum* seed bank will begin to germinate and thus lead to our next method of reduction before replacement. A high-intensity, early spring grazing regime will limit *L. multiflorums* additions to a further reduced seed bank (Smoliak et al 1981; Gulmon 1979). In our case grazing may be an effective control strategy. However, cattle grazing may have negative drawbacks by creating a need for monitoring impacts to wildlife and changes in soil bulk density, infiltration and/or compaction (Tate et al 2004). At this point in time representative random samples of the top soil layer must be collected and placed in a green house in conditions similar to those needed to induce *L. multiflorum* seed germination. If the green house results suggest the *L. multiflorum* seed bank has been significantly reduced, we would then be clear to move forward in phase I. If the levels of germination have not been reduced to threshold levels of eminent extirpation, the *L. multiflorum* control practices should be continued till such a point in time.

Ideally the state of our site will be disturbed enough for the facilitated transition to the next step of phase II. Our goal of the later half of phase II involves replacing the *L. multiflorum* niche with a diverse suite of natives including but not limited to: *Bromus carinatus, Nassella Pulchra, Leymus triticoides, Asclepias fascularis, Grindelia camporum* and *Eschscholzia californica*. The collection of species will initially be broadly distributed by mechanical seed dispersal in early spring time. A year after seeding, vegetation monitoring for species spatial distributions and establishment will indicate the need for transplanting or further seeding of specific species in properly suited areas. After our desired state of a mosaic of patches of grassland and prairie is attained, a low to moderately intense grazing and low intensity fire regime will likely be continued in the land management strategy.

Currently in a section of the restoration site, persists a thicket dominated by a non-native invasive *Rubus discolor*. The thick overgrowth possess a significant fire hazard to the near by WFC Fisheries facility and should be eliminated. The *R. discolor* species has proven to be sensitive to shade as a seedling, goat herbivory and glyphosate, which may be promising weaknesses to utilize in our attempt to convert this section to valley oak (*Q. lobata*) woodland (DiTomaso and Healy 2007). The initial treatment in Phase III will include a short, high intensity goat grazing regime occurring in the first fall and will be intended to decimate the *R. discolor* stand.

Even though seeding of the commercially available non-native *L. multiflorum* and native *Bromus carinatus* poses some risk of spreading to nearby areas, more importantly both are resistant to glyphosate, *L. multiflorum* is relatively inexpensive as seed and both can be selected over the *R. discolor*. Ideally the seed cocktail choice will lead to a fast establishing, dense grassland community shortly after the first rains of fall. Coinciding with establishing the *L. multiflorum, B. carinatus* community, a site dosage of glyphosate will probably inhibit any sucker sprout responses from the recently cleared *R. discolor* thicket.

The next transition in our phase II plan involves a period of time to allow the grasses to form dense mats of residual dry plant matter, alternated annually by periods of mowing. The use of this method intends to create a shady canopy to suppress the possibly remaining seed bank of *R, discolor*. Upon the successful inhibition of *R. discolor* species, determined by point-intercept, quadrat transect sampling techniques, our restoration plan shifts focus from species reduction to species replacement. Our objective is to facilitate the establishment of caged seedlings sourced from nearby *Q. lobata* populations. The purpose of using nearby populations relies heavily on the assumption locally established trees have the necessary genetic disposition needed to effectively compete and persist under local conditions. Seedlings need to be used due the effectiveness of *L. multiflorum* and *B. carinatus* at suppressing seed establishment. During the period transition of seedling to sapling nearby grasses should be suppressed by grazing or mowing. The practice will provide two benefits: one being a decrease in fuel load and fire risk, two it will favor oaks by decreasing competition for water and nutrients. The temporal scale of this phase extends decades rather than years like the other phase due to the long-lived life history strategy of oak species. At the time of valley oak woodland canopy formation the establishment of native perennials, such as *Nassella pulchra*, may be possible due in part to shade sensitivities of *L. multiflorum* and other invasive species. The valley oak woodland may require periodic low-intensity grazing and low-intensity burning of understory to maintain native species.

Key limitations to our restoration projects involve the unexplored method of using *L. multiflorum* to control community dynamics. The monitoring of control plots and treatments may provide insight into the viability of using *L. multiflorum* and *B. carinatus* as community control agents. More understanding of trophic interactions may be useful in adapting management practices to positively influence system dynamics. Furthermore a full array of monitoring vegetation and animal communities prior to restoration and their respective responses to restoration is needed to increase the projects success.

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Exotic forb species

Clara Laursen

Brassica invasion

ENH 160 Project Part I

The Spring 2009 ENH 160 class should recommend complete eradication of all *Brassica nigris* and *Brassica rapa* from the 60 acre plot of UC Davis land entrusted to us. Total eradication, and continued monitoring and removal of immigrant individuals, would provide a variety of significant benefits that range from recreating the local native ecosystem to reducing financial losses in agriculture.

UC Davis, which is famous for its interest in wildlife conservation and environmental health, should be glad to help fight the enormous ill effects these nonnative plants have on the ecosystems they invade. By effectively excluding all other plants from these stands, these two mustard species decrease the population sizes of native plants, affecting the density and distribution of native wildlife, which can make little use of the mustard plants for food or shelter. One such native plant that is adversely affected by mustards is a Californian native bunchgrass, *Nassella pulchra*, which is an important food source for many native rodents and other granivores (Orrock 2008). Rodent populations, which cannot survive on mustards, are crucial to the survival of prized animal species that could exist on our restoration site, including the white-tailed kite.

Because mustard invasions occur throughout California, any additional data regarding eradication efforts would be welcomed into the scientific community and thus supporters of our restoration project would reap the benefits of prestige in addition to the satisfaction of having helped native plant and animal species. *Brassica nigris* and

Brassica rapa have spread their way across all but a few states of the continental United States, after originally making their way to America from Eurasia (Lorenzi 1987).

> These mustards' highly effective methods of dominating so many other plant species means that they have become a threat to agricultural activities. Since agriculture is a primary interest of both California as a state and UC Davis as a university, threats to agriculture should not be taken lightly. Mustards primarily infest small grain and flax fields, where they can be a serious problem unless treated with herbicides (Lorenzi 1987). Delays in eradication efforts are likely to lead to further spread into agricultural arenas. Studies have suggested that this pest species evolves particularly rapidly and will thus likely be capable of spreading into new ecosystem types and surviving global climate changes (Franks 2008).

Lastly, UC Davis may have an interest in removing *Brassica nigris* and *Brassica rapa* to increase human enjoyment of the area. Although the mustard plants do produce hundreds of tiny yellow flowers, the plants are green only seasonally and spend much of their time resembling brown tumbleweeds. Aside from being aesthetically displeasing, these mustard species are very difficult to walk through, as they grow to be up to 1.5 meters tall with strong intertwined branches. Furthermore, *Brassica nigris* usually has bristles on the lower branches (Lorenzi 1987).

All of these benefits to eradicating *Brassica nigris* and *Brassica rapa* should be enough to convince potential sponsors to provide funding for restoration on the plot. Sources of funding may be available from Non-Government Organizations with a special interest in the conservation of threatened species currently or historically found within the boundaries of the 60-acre plot. The Audubon Society branch located in Winters is a likely sponsor. Aside from direct financial sponsorship, aid in the form of volunteers may be elicited from nearby schools, grassroots environmental groups, or other similar local sources. Depending on the method of restoration chosen, labor may well be a big cost.

Many restoration methods have been attempted to reduce *Brassica nigris* and *Brassica rapa* numbers. A variety of biotic and abiotic factors must be considered before a method is chosen for this restoration effort. A study of existing knowledge about *Brassica nigris* and *Brassica rapa's* natural history provides insight into how this plant spreads and survives under various conditions. A good understanding of the plants' physiological limitations will help us understand what factors about their environment we need to change in order to affect their survival and reproduction.

Perhaps the biggest reason *Brassica nigris* and *Brassica rapa* have such devastating effects is their ability to quickly and consistently form nearly pure stands (Bell 1973). Bell states that these mustards employ a form of interference to take over native plants. Interference can be defined as the sum of all hardships suffered by one individual due to the proximity of another individual. In the case of these two mustard species, the primary form of interference used is allelopathy. Allelopathy refers to a method by which one plant chemically inhibits the growth of another. A toxic chemical compound, allyl isothiocyanate, is released by mustard plants. Any part of the mustard plant, including leaves, stems, roots, and seeds, contains this toxin and will release sufficient quantities into the soil nearby to prevent germination of other plants. Furthermore, the plant does not even have to be alive to leach this toxin into the soil. Dead plant parts contain allyl isothiocyanate as well (Bell 1973). Because allelopathy occurs underground through roots and above ground through dead plant parts, restoration efforts to merely mow the plants will not succeed in eradicating the mustards. If all plant parts are successfully removed from soil, the toxin will still take about nine weeks to dissipate (Weston 2003).

> Burning or mowing solves the problem of leaving toxic plant matter above ground, and if timed correctly can provide enough time for the underground roots to die and decompose enough to stop emanating toxins before the next germination period. Grazing is not an option as mustards are not edible to grazers (Orrock 2008). One

study found that the best time to remove ground cover was April, before the mustards started dropping seeds to the ground (Moyes 2005). This would prevent the seed bank from being replenished that year.

However, several obstacles and drawbacks exist to burning. Aside from the potential danger that any fire presents to people and property, restoration ecologists must overcome air quality restrictions. Fires contribute a significant amount of pollution to California's already suffering air quality (Lorenzi 1987). Burning as a restoration tool is sometimes avoided due to the fact that it does not selectively kill only the target pest plant, meaning that many native plants may be killed and this may cause an undesired shift in ratios of native species. However, because mustards typically form nearly pure stands, this drawback is largely irrelevant in this case. More relevant to this study was the discovery of large surviving seed banks from previous years that provided for a new population of plants the following season (Moyes 2005). A very thin layer of soil will protect seeds from fire damage (Lorenzi 1987). Thus, even the complete removal of mustards and their toxin above ground will not effectively exterminate a population and its allelopathic effects.

Several methods have been employed to exterminate the seed bank, including herbicide and solarization. These methods are key to eliminating mustards, as seeds are the only way they reproduce. Herbicides of many types exist, and although they are all likely to have negative effects on the environment, this damage is minimized by the fact that all herbicides must be approved by the Environmental Protection Agency before being marketed. So far, an herbicide called 2,4 D has been used successfully in agricultural field settings (Lorenzi 1987). Solarization is a very labor-intensive method, but does work well without introducing harmful chemicals to the environment. This method involves covering barren soil (made barren through burning or other mechanical removal of plant matter) with a layer of plastic. The plastic soaks up the sun's heat and traps the soil's moisture to create a very hot and humid environment that is deadly to the seed bank (Moyes 2005).

Although solarization kills all seeds in the seed bank, including any surviving native plant seeds, this tradeoff is minimized for two reasons. Firstly, the native seeds in a mustard dominated stand would never have the opportunity to germinate as long as the mustard population remained. Secondly, our restoration patches are small enough that native plants can either make their way back into the land from neighboring sources, or we can seed the area with desired native plants.

In addition to allelopathy, these two mustard species conduct interference through direct competition for resources. Various biotic and abiotic factors contribute to invasive plants' potential to out compete native species. These factors include, but are not limited to, soil depth, soil moisture, sunlight, slope, and water availability (Morghan 2004). Invasive plants, such as *Brassica nigris* and *Brassica rapa*, have a wide range of acceptable microenvironments that allows them to exploit more resources and survive and thrive in more conditions. However, mustards occur primarily in open fields with abundant sunlight (Lorenzi 1987). Understanding the current abiotic conditions in the study area is necessary to allow the class to know what needs to be done to create environmental conditions favorable to native species. For example, before burning is prescribed, research should be done to determine how the native plants will respond to increased nitrogen in the soil. In one study, scientists found that burning converted a patch of land from grassland to mostly forb domination due to increased soil nitrogen levels. (Moyes 2005). Successful establishment of native species is helpful in preventing recolonization of nonnative plants (Lyons 2002).

It is very likely that a combination of restoration efforts will be needed to remove plants above and below ground to prevent mustard communities from recovering. Neighboring plots are likely to have mustard plants, so windblown seeds are likely to make their way to the plot. Continued monitoring and periodically repeated eradication efforts will be needed. However, the eradication method may be different once the mustard population is smaller and more scattered.

There are currently a few factors that require answers before a restoration plan can be chosen. A thorough survey of the restoration plot should be conducted to determine plant and animal species composition. Care should be taken to ensure that rare native species are not unintentionally harmed by a restoration method. Furthermore, the restoration plan chosen for mustards should be compatible with restoration goals for other class focal species.

Part II

A. **Key Goals**

a. **Short term**: Achieve eradication of pure stands of both *Brassica nigra* and *Brassica rapa*.

Ideally, we would aim at complete eradication of both mustards, as they are nonnative and to our knowledge they perform no biotic or abiotic service to native plants and wildlife (Orrock 2008). However, eliminating every individual would be extremely labor intensive and/or expensive, given that a few individuals are found widely scattered around the restoration plot (Classmates 2009). Instead, I recommend a compromise that takes care of the most damaging plants (those in pure stands).

To ensure that mustards do not immediately recolonize, I recommend seeding/planting desirable plants immediately after the solarization plastics are removed. The decision regarding which species these should be will be made by the class after taking into consideration many factors and goals, but mustards would be least likely to recover if the plants planted after solarization provide deep shade (Lorenzi 1987).

b. **Long term**: Maintain an absence of pure stands of *Brassica nigra* and *Brassica rapa*.

Because mustards are so efficient at reproducing and expanding their stand size, I recommend annual monitoring of mustards. April would be the best month to conduct surveys to find new or renewed pure patches. At this time the mustards will have matured enough to be easily visible but will not have contributed to that year's seed bank yet.

When new pure (or near pure) patches of mustards are discovered, they should be eradicated with solarization immediately.

I anticipate that the first year of restoration will likely cost much more than subsequent years. Past studies have demonstrated success with solarization, so as long as new seeds from nearby do not replenish the area, the only possible need for solarization in later years will be if the few scattered plants expand into pure patches.

B. <u>Restoration Plan</u>

Analysis of past studies indicates that the best eradication plans for *Brassica rapa* and *Brassica nigra* are herbicide or solarization.

a. Herbicide:

Many types of herbicides will kill these forbs. 2,4 D has been most widely used in agricultural settings. Application is recommended to occur in early Spring (Lorenzi 1987).

This option satisfies the goal of eliminating mustards, but may be unacceptable for the class project due to the cost and the difficulties of obtaining and physically distributing the herbicide. Furthermore, there may be undesired consequences to applying herbicides. 2,4 D and other herbicides kill many plant species, so application of 2,4 D may kill native plants.

Herbicides may also directly or indirectly injure or kill wildlife, either by being ingested or by collecting in the nearby pond. This could pose a serious threat to our goal of conserving wildlife such as kites and turtles.

b. Solarization:

Solarization has been demonstrated to be effective in destroying the seed bank of mustards, which otherwise survives many years. Seed banks also survive other nonnative control methods, such as fires and mowing. Nonetheless, some form of above-ground vegetation removal must occur before the solarization can be done (Moyes 2005). Above-ground removal can be done in whatever method best serves any other goals of the class. For example, if the patch of mustard lies within an area affected with a nonnative that is best treated by burning, then burning may be conveniently used in the whole area.

Once above ground vegetation removal is complete, large plastic sheets must be laid on the barren soil, weighted down, and left for several weeks, depending on the weather. Sunnier, hotter weather would require fewer weeks (Moyes 2005), which may be a valid reason to push back the start date to late rather than early April.

Like herbicide, solarization has the drawback of killing more plant species than just the mustards. However, because we will be focusing on relatively small patches of virtually pure stands of mustards, these losses will be minimized. The effects of solarization are also extremely localized, with no accidental runoffs to water sources or ingestible toxins. Burrowing animals would still be at risk, so a survey for burrowing animals of conservation concern, such as tiger salamanders, should be carried out prior to laying down the plastic.

Because our restoration plots are relatively small, I think sufficient labor would be available through volunteers. The cost of the plastic sheets is relatively inexpensive at approximately five dollars per ten square feet.

The duration of time solarization must occur depends on the weather. Hotter, sunnier weather allows shorter amounts of time. If summers are hot and sunny, then solarization can be finished as early as mid June. Nine weeks later, in early fall, when we are certain the allelopathic capabilities of mustards have been stopped, revegatation should occur to help prevent mustards from reinvading. However, if solarization is not started until after April or if it must run into late summer, project managers should consider waiting to revegetate until Spring to avoid allelopathic effects from interfering with fall revegetation efforts.

C. **Further research:**

This restoration project would provide an excellent opportunity to study competition between these mustard plants and other nonnative plants. The possibility of using mustard's allelopathy to control other invaders would be fascinating and applicable to similar restoration projects, where it may be easier to introduce mustards to replace another invasive and later control the mustards. This study could be carried out by planting mustards among various nonnative species, and then monitoring the survival of both species. The study should have a control group consisting of nonnative plants in similar conditions as the plants into which the mustards were introduced.

Part III

The goals and methods for controlling mustards are highly compatible with the class' other key goals and methods for the restoration of the plot. The best plan for mustard eradication is mowing or burning followed by solarization in April. Conveniently, the best plan to eradicate most other nonnatives and then plant natives is mowing, burning, or grazing in Spring. It is thus easy for the class to accommodate mustard's control facts by excluding grazing as an option and choosing April as the month in Spring to take action.

The control plan presented in this paper could only be marginally strengthened if other class goals were ignored. If the class' only goal was to control mustards, the best plan would be to solarize the entire plot and then re-establish native plants. However, this plan has several drawbacks. This plan would only achieve complete eradication temporarily. The landscape effect suggests that seeds from nearby unmanaged plots would reach the plot and establish. Continuous monitoring and eradiction is therefore necessary under both this plan and the plan that is compatible with the class' other goals. Secondly, this plan would be significantly more expensive than focusing only on nearly pure stands, as it would require much more materials and labor. It would also risk killing any rare native plants that currently exist either above ground or in the seedbank.

On the other hand, the plan that is compatible with the class' other restoration goals would not risk killing fewer rare plants existing above ground or in the seed bank, would cost much less, and still remove a very large proportion of the mustards in the plot, and reach nearly the same long term efficacy.

Original Plan: Complete Eradication	Revised Plan: Eradication of Pure Stands Only
(Diagram)	**(Diagram)**

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Hana Yokoyama-Hatch
ENH 160

The Invasion of a Prickly Plant: Yellow Star Thistle

PART ONE:

Section A. Affects and Effects of Yellow Star Thistle

Yellow star thistle (YST) has numerous effects on ecological communities and humans. It invades disturbed areas such as roadsides, parks, pastures, recreational areas, and fields. YST is so competitive that it can choke out other plant species thereby decreasing plant diversity. (DiTomaso, 2006)

In rangelands, YST can be both beneficial and detrimental to farmers. During the beginning stages of growth YST is a good source of protein for grazers. But as the plant age's protein and nutrient content decrease thereby decreasing forage quality. (DiTomaso, 2006) As a result, the amount of grazers a rangeland can support is decreased (Roxana et. al, 2007). A study done in Idaho, revealed that YST cost over $12.7 million dollars in revenue (79% loss was attributed to the decrease in agricultural benefits of rangelands) (Roxana et. al, 2007). YST also causes chewing disease in horses which can be and usually is fatal (DiTomaso, 2001).

While no thorough studies have been done, YST is a main source of nectar for bees (DiTomaso, 2006). If complete eradication of YST is not achieved, it can still support some positive interactions.

Section B. Broad Goal

My broad goal is to prevent and control the establishment of yellow star thistle populations. I want to focus on these areas.

1. Prevent and contain the development of new YST populations
2. Reduce YST biomass in infested areas
3. Aim for complete eradication of all YST populations
4. Restore infested areas to the original native vegetation (through competitive species) and/or land use

Section C. History and Mechanisms of Spread

Yellow Star Thistle (YST) invaded the US by seed. It was first detected in 1849 when it was discovered in a Chilean Alfalfa bale. Following its detection, YST began to expand to other agricultural fields, roadsides, etc. Between 1920-1940, YST populations declined due to a change in farming systems (specifics of this change were not described). But it continued to expand. In 1930 YST began to invade California's foothills where it became a prominent weed in grazing systems. By 1958 YST had invaded one million acres in CA. Then in 1960 three major causes increased its spread: extensive road building, increasing suburban development and ranching areas. But in a short twenty-seven years, YST invaded more than eight million acres. Since then YST populations have invaded nearly fifteen million acres and are expected to expand. It is a noxious weed that has been classified as invasive in California, Idaho, Wyoming, Utah, and Oregon. (DiTomaso, 2001)

Humans are the primary mechanism of spread across the US. Seeds can attach to clothing, livestock, birds, or to the tires of vehicles. Also, hay bales that originated from effected pastures can bring seeds to unaffected areas. When exiting infested areas you should check for obvious foliage attached to yourself and others as well as all vehicles. YST seeds have stiff bristle so it can easily attach to your clothing or fur. Birds can also disperse seeds. (DiTomaso, 2001)

Section D. Biology and Effect of Yellow Star Thistle

Originally from Africa and Mediterranean regions in Europe, yellow star thistle (YST), *Centaurea solstitialis* L., is an herbaceous winter annual that belongs to the Asteraceae family (Czarapata, 2005). It is an aggressive colonizer that has three distinct phases of development: seedling, rosette, and adult (Larson et. al, 2008). Best adapted to open grasslands, YST thrives in full sun with well-drained soil and 10-60 inches of annual rainfall (Czarapata, 2005). YST can grow up to three feet tall and have a six foot long tap root (Czarapata, 2005; DiTomaso, 2006). YST foliage is grey to blue-green. Its leaves have a cottony wool surface. The basal leaves are deeply lobed and about two to three inches long whereas the upper leaves are narrower and not as lobed. It has bright yellow flowers that have sharp spines at the base of the flower head. (Czarapata, 2005)

YST germinates in the fall and completes its life cycle by the next summer. Beginning in fall, YST plants begin to germinate. By spring, YST seedlings transition into the rosette stage. Then in late spring the rosettes begin to bolt (formation of flower stalk). By summer (around May) YST begins to bloom. YST is monoecious and is cross-fertilized by honeybees. There are successive stages of bloom. Bloom proceeds in the following stages: full spiny, pre-bloom, flower initiation, flower expansion, full bloom, initial, middle, and, late senescence, then petal abscission and finally ache dispersal. Viable seed are developed between late senescence and ache dispersal. (DiTomaso, 2006)Understanding the different stages of bloom is important because the success of control methods depend on this factor.

YST reproduces by seeds. YST can bear either pappus or non-pappus seeds (DiTomaso, 2006). Pappus seeds have long hairs to aid in wind dispersal. One YST plant can be responsible for new infestations as seeds can easily fall two feet from the parent plant(Larson et. al, 2008). Under optimal conditions, a YST plant can produce over 150,000 seeds. Also, 60% of seeds produced by a YST population can be available for germination after dispersal (Larson et. al, 2008). Furthermore, seeds can lay dormant for ten years (Larson et. al, 2008).

Section E. Continue

The following control methods will be explained in greater detail in part two.

Mechanical Methods

- Hand pulling, hoeing
- Mowing
- Tillage
- Grazing
- Prescribed burns

Chemical Method

- Herbicides: Transline, Round-up, Telar, Tordon, Weedone

Biological Control

- Re-vegetation
- Beetles and Weevils
- Fungus

Section F. Ideal and Model Management Plans

The ideal management technique is a long-term (>3 yrs) integrated management plan where necessary control methods differ per location. In general, most management strategies attempt to assess infestations, determine, and, control populations, and set-up management plan. The following are brief examples of past management plants.

- Rangelands: Herbicides with re-vegetation of perennial bunchgrasses (DiTomaso, 2006)

  In this six year experimental study, clopyralid and glycophosphate were applied to the infestation to allow the introduction of wheat grass. The application of clopyralid proved successful in controlling YST. Glychophosphate also proved successful in maintaining wheat grass populations. Within one year, wheat grass was successfully established and continued to thrive. However, in the last year of treatment the experimental plot was re-invaded by YST.
- Grasslands: Prescribed burning with the use of the herbicide Cloprylaid (DiTomaso, 2006)

  In this study, researchers found that the results differed differed by application time. When Clopyralid was applied in the first year and a prescribed burn was done in the following year, YST populations increased because the burn stimulated YST germination. But when a burn was done in the first year and clopyralid applied in the following year, YST populations were almost completely controlled. Most likely the burn spurred YST germination. But the application of the herbicide prevented growth.
- Mowing, Grazing, and re-vegetation with clovers (DiTomaso, 2006)

  In this study, researchers achieved 93% control of YST. They conducted seeding with subterrean clover, three grazing regimes, and mowing during early flower development.

Section G. Main Factors and Constraints Affecting Management Practices

Constraints

- *Hand pulling:* labor intensive, can cause injury if done during spiny seed head development
- *Grazing:* animals could compact soil, require management and fencing unit, can injure grazers during spiny seed head development
- *Tillage:* non-selective, not suitable for basin areas, can promote the growth of other invasive plants
- *Herbicides:* need to choose a herbicide that will not impact water quality or kill existing natives, be aware of herbicide drift, his/her own safety, county and state regulations

- *Mowing:* only destroys above ground foliage, not suitable for basin areas, can generate sparks
- *Prescribed burn:* risk of fire escape, effects on air quality, proximity to nearby buildings, wildlife mortality
- *Re*-vegetation: may introduce a more invasive species
- *Biological control:* may displace current insect populations with YST insects

Factors:
- Appropriate timing of applying control methods
- Location of infestations; some areas may be inaccessible
- What is the terrain in the infested area?
- Is it a rangeland, wildlife area, recreational area, private, public land?
- How much money will you need?
- What are the county and state restrictions on recreational and public areas?

Section H. Laws, policies, and organizations

Organizations:

The following are potential organizations that could assist in the management and control of YST:

- *Federal*: National Park Service, United States Department of Agriculture, United States Bureau of Land Management
- *State*: California Department of Food and Agriculture (CDFA), Cal Trans, CA Department of Parks and Recreation, and CA Department of Forestry and Fire Prevention
- *Local*: Cooperative Extension, County Ag Commisioner

Legislation:

- 1999 Assembly Bill 1168: Generated $200,000 a year for three years to the Weed Management Areas to assist in mapping and control of YST (DiTomaso, 2006)
- 1999 Executive Order 13112: Assisted in the formation of the National Species Management Plan which focuses on the control of all invasive taxa (DiTomaso, 2006)
- 2000 Senate Bill 1740: Generated $5 million dollars in funds where $4,500,000 was directed towards control of invasive species (DiTomaso, 2006)

Additional Sources of Information:

- National Invasive Species Council
- Invasive Species Advisory Council
- California Weed Action Plan
- California Invasive and Noxious Weed Coordination Committee
- CDFA Pest Prevention System
- Center For Pest Research and Extension
- Western Society of Weed Science
- Local Expert Joseph DiTomaso at University of California, Davis

Section I. Sources of Funding

The above organizations could provide funding or direct you towards other organizations. Ranchers, farmers, public and private landowners may also be willingly to financially assist in management and control of YST on their properties.

Section J. Additional Information

If total eradication is not achieved, YST could be used to generate small funds. YST produces honey which can be enjoyed by humans. According to Moon Shine Trading Company, the sale of one sixteen once jar generates nine dollars and fifty cents (Buffalo Web Service, 2009) ! If one hundred people bought one of these jars where half the proceeds went towards the restoration and management plans, you could generate four hundred and seventy five dollars!

Section K. Gaps of Knowledge

- Further research needs to go into determining the effectiveness of plant pathogens as a biological control measure.
- Is there a common pattern of responses after management? Will management plan x cause response x in area x?

PART TWO:

Managing YST requires a long-term integrated management plan. The Putah Creek Reserve needs to focus on the reduction of current YST populations, the prevention of new-infestations, aim for complete eradication of YST populations, and the restoration of the infested areas. In the short term, evaluating current YST populations through mapping techniques should be a key goal. In the long term, eradicating and preventing the establishment of new YST populations should be key goals. In the final stages of YST management, infested areas should be returned to their original species composition. Furthermore, the management plan needs to be aggressive and well-planned in order to have success.

Mapping Putah Creek Reserve should be of priority. By mapping the area, you can evaluate the current populations and establish areas of high density as well as use it for evaluating pre and post YST infestations. Therefore, mapping must be annual task. Mapping can be accomplished through quadrant or transect sampling, GPS and GIS systems as well as aerial remote sensing equipment (DiTomaso, 2001). While a plant density scale was not found, prioritizing areas of high and low infestations would be beneficial. Since Putah Creek Reserve is a large area of land, sectioning off pieces of land (<2 acres) may be an alternative way to prioritize the area. Furthermore, mapping allows you to determine the most effective control methods for the site as well as monitor the successes and failures of the management plan (DiTomaso, 2001). Once mapping is done, the data needs to be compiled into a Microsoft Excel book or a public online database. After mapping has been accomplished, management procedures must begin.

The main goals of YST management are to prevent the development of new infestations, reduce YST biomass in infested areas, and aim for complete eradication. So YST control procedures must be carefully evaluated and well-planned.

Control Methods:

Note: please see control method chart to compare the different control methods.

A. Mechanical methods:

Hand Pulling: Hand pulling should be done after bolting but before the first bloom. It is best for light infestations or removing isolated plants. Removing the plant "prevents seed production and slows re-establishment" (DiTomaso et. al, 2000). But one must ensure that all above ground foliage is removed to prevent re-growth. Despite this, it is a relatively easy method that requires little preparation and money. (DiTomaso, 2006)

Mowing: Mowing should be implemented before the spiny seed head develops. If not, there is a risk that you could increase the population size. Results also depend on the shape and structure of the plant where the more erect plants suffer the most. It would be an effective method for light infestations during the later part of the year. (DiTomaso, 2006)

Tillage: Tillage should be done before viable seed is produced (approx. late senescence bloom). Tillage is great for agricultural and urban areas with high YST infestations. It can be implemented at the end of the rainy season or whenever the ground is soft enough to till. Tillage will completely destroy all of the YST plants. But you must keep in mind that it is not a selective control method and could increase soil erosion as well as encourage other noxious weed growth. (DiTomaso, 2006)

Grazing: Grazing should occur after the plant has bolted but before the first stage of bloom (DiTomaso, 2003). Sheep, cattle, and goats are the best animals for the job. Goats are the most effective grazers as they continue to graze after the plant has produced the spiny seed heads (DiTomaso, 2003). To ensure the animals health proper timing is vital. If the spiny seed heads have developed the animals could suffer eye injuries. Also, horses can not be used as grazers. YST is toxic as it causes chewing disease which causes paralysis and even death. (DiTomaso, 2006)

Pre-scribed Burns: Prescribed burns are most effective towards the end of June and early July. During this time YST should be in the early stages of bloom or in the during the late senescence bloom. Burns can encourage native plant growth such as legumes and perennial grass as well as kill other invasive plants such as Ripgut Brome (Bromus diandrus) (Hasting et. al, 1996). Burns also release nutrients held in vegetation. An experiment done by Joseph DiTomaso and Marla Hastings, in the first year, resulted in a 100% prevention of new seed production because existing plants were completely destroyed and a 74% decrease in the soil seed bank (Hastings, DiTomaso). The following year a second burn was done. This time there was 90% decrease in YST and a 99% decrease in soil seed bank (Hastings et. al, 1996). During each burn an increase in natives was observed. However, there are some downsides. If biological control methods were used in previous seasons burning will kill those organisms. So proper planning is necessary. As always, there is a risk that the fire could escape. Prescribed burns must also be done on good air quality days otherwise fines could be incurred. (DiTomaso, 2006)

B. Chemical Methods:

Herbicides: There are quite of few effective herbicides that kill YST. Some are better as pre-emergent's or post-emergent's. So depending on the time of year and location careful selection of herbicides must be done. The following will briefly go over the most common herbicides used in controlling YST.

1. Transline (active ingredient: Clopyralid) is the best herbicide for controlling YST (UCD, 1997). Transline is a pre- and post-emergent herbicide (UCD, 1997). It has little toxicity, doesn't affect grazing regimes or cause damage to grasses and broadleaf plants. It best applied in late fall to early spring and is most useful for first and second year control regimes. It can be applied by air or ground (UCD, 1997). However, the herbicide takes at least two months to kill YST (UCD, 1997).
2. Round-up is an effective late-season herbicide for spot treatment. It is ideal for controlling small infestations. It is best applied between the bolting and early flowering stage. However, it is a non-selective herbicide so care must be taken when spraying in diverse communities. (DiTomaso, 2006)
3. Telar (active ingredient: Chlorsulfuron) and Escort (active ingredient: Metsulfuron) are effective pre-emergent herbicides. They should be applied in late winter or early spring with 2,4-D, dicamba, and/or triclopyr. However, it is not registered for use in non-crop areas and is not as commonly used in YST control. (DiTomaso, 2006)
4. Tordon (active ingredient: picloram) can be used as a pre and post-emergent. It doesn't damage grasses. However, it has few issues. Picloram remains active in the soil, can cause herbicide resistance, and some forms are not registered in California. It is also a groundwater contaminant. (DiTomaso, 2006; Kegely, 2009)
5. 2,4-D, Banvel (active ingredient: dicamba), and Garlon/Remedy (active ingredient: triclopyr) are late-season, broad-leaf post-emergent herbicides. They work best when applied to seedlings and can be used when YST is near perennial grasses. (DiTomaso, 2006)

C. Biological Control:

Bio-control can be used year round. There are four insects that are used to control YST: Seed-Head Weevil (Bangasternus orientalis), Seed-Head Fly (Urophora sirunaseva), Hairy Weevil (Eustenopus villosus), and the accidentally released False-Peacock Fly (Chaetorellia succinea). Of the four the False Peacock fly and the hairy weevil have the most impact on YST. A study demonstrated that the use of these two bugs together can "reduce seed production by 43% to 76%" (DiTomaso, 2006). There is also a rust fungus, *Puccinia jaceae,* that can be used as a biological control method. The fungus attacks the leaves and stems of rosettes and before YST bolts. The fungus stresses the YST flowerheads thereby decreasing seed production. It is highly specific and will only infest certain YST species. However, it has only been released at few sites across California. (DiTomaso, 2006) Further research needs to be done to evaluate other potential effects.

Re-vegetation: Re-vegetation must be done with other control methods. It is a long-term method that requires an integrated approach that fits the need of the location. One of the biggest obstacles for re-vegetation is growing a plant that is just as invasive as YST but will not become a weed itself. A study done in 2004 found that decreasing species richness resulted in higher YST populations (Zavaleta et. al, 2004). A specie rich community that was competitive with YST included late-season forbs and perennial species (Zavaleta et. al, 2004). As a result, YST populations diminished. Usually, the best competitive species are non-natives perennials such as Tall Oat grass and Crested Wheat grass.

Suggested Strategies:

The following strategies are based on the level of YST infestations as well as site specifications determined in ENH 160 lab. For small scale infestations, use hand pulling, and spot herbicide treatments. For large scale infestations, you have the choice of using tillage, grazing regimes, prescribed burns, biological control, and broad applications of herbicides. Based on preliminary vegetation sampling in basin 3, there appears to be other large populations of invasive weeds. Based on this, tillage should not be used as it has the increased capacity to allow the expansion of invasive weeds more so than native plants. Also, grazing should only be used in the flat land areas of the reserve. If grazing occurs in the basin areas the animals could further compact the soil. As a result, further soil testing should be done to determine where grazers can be put. Since there are other invasives, a prescribed burn could be advantageous. However, if prescribed burns are used, biological control can not be used. Therefore, mowing, herbicide, and, prescribed burns are the best management practices for Putah Creek Reserve.

Following the successful control of YST, the re-vegetation process must begin. YST can not "survive well in shaded areas, and is less competitive in areas dominated by shrubs, trees, taller perennial forbs, grasses, [and/or] late season forbs (DiTomaso, 2001). As a result, re-vegetation must be done with every management plan. Recall that YST is an aggressive colonizer. So finding plant specie that is just as competitive but will not turn into a nuisance itself will be a difficult task. In past experiments, the following species are were considered: Tall Oatgrass, Crested Wheatgrass, Intermediate Wheatgrass, Sheep fescue, Big blue grass, and Thickspike Wheat Grass (DiTomaso, 2001). While further research needs to be done, the "incorporation of deeply rooted summer forbs or shrubs into perennial grassland restoration projects may be beneficial" because these plants will be using water deeper in the soil profile where YST also gets its water (Enloe et. al, 2004). In this paper, Enloe separated the infested areas into different plant communities. In one community, the YST was sprayed with transline at 70 g/ha during March. As a result, the plot had 50-90% annual dominance. A follow-up treatment a year later occurred during the same time and was applied at 105 g/ha. In another community, the area was prepared for seeding through the broadcast application of glyphosate at 330 g/ha during February. Following that, the area was seeded with Pubescent wheatgrass (Thinopyrum intermedium) and transline (Enloe et. al, 2004). Furthermore, there is a possibility that the re-vegetation process will fail and be out-competed by YST. Thus it is absolutely necessary that the re-vegetation process be constantly monitored to ensure its success.

Finally, prevention is a key step towards maintaining a relatively YST free area. Prevention measures require early detection and eradication of new infestations. In the field, preventative measures can include the daily checking of vehicles, shoes, clothing, and agricultural machinery as well as ensuring re-vegetation seeds are weed-free. Careful monitoring of managed areas should also be done regularly.

Suggested Plan:

Year One: Prescribed burn to kill off YST or mowing infested areas
Year Two: Broadcast or spot application of Transline, begin re-vegetation process
Year Three: Follow-up procedures to prevent a re-infestation of YST (DiTomaso, 2001), continue re-vegetation process

Potential Problems:

- ❖ Seeds for re-vegetation process must be certified weed-free to prevent the introduction of invasive weed seeds (Harper et. al)
- ❖ Re-vegetation process may be unsuccessful or difficult to manage
- ❖ Timing the management plan appropriately according to the control method used

Risks and Uncertainties:

The management plan you implement may not result in the response you expected.   For example, the plants used in re-vegetation may become invasive themselves or will not overtake YST. Or the implemented herbicide treatment negatively effects current native plant populations. There will be a trade-off for most control methods. Please see the control method chart for the pros and cons of each method. As a result, regular monitoring efforts are absolutely required.

Research Questions:

- ❖ Since the Putah Creek Reserve involves multiple ecological communities, will the effective management strategies implemented help other similar areas battle YST infestations?
- ❖ What were the successful plants used in re-vegetation? How long did it take for them to become established?
- ❖ Can the mapping data gathered at the site be used to develop a specie richness profile?
- ❖ Will planting seeds or seedlings result in higher re-vegetation success?

Spatial and Temporal Chart

Goal	Spatial	Temporal
Mapping Putah Creek Reserve	Across entire property or in areas where YST is visually present	One month
Control of YST	Across all populations, focusing on high density areas	Containment of YST should be accomplished within one year but may take longer than three years depending on the levels of infestation. Control may have been successful but there is a potential that the seed bank will germinate as YST seeds can lay dormant for 10 years.
Prevention of YST	Across all populations focusing on roadsides, and disturbed areas	Continuous year round effort.
Implementation and establishment of Re-vegetated areas	In all areas where YST control and/or prevention occurred.	After successful control of YST has been reached. Extensive monitoring must also be done to ensure the success of the re-vegetation process. This should be a weekly process during the beginning of planting. Following that, a monthly process.

YST Control Methods (DiTomaso, 2006)

CONTROL METHOD	TIME OF YEAR TO BE APPLIED	STAGE OF YST GROWTH	PROS AND CONS
Hand pulling	-this is a late season treatment -specific months not specified in literature	-after bolting to early flowering	Pros: -cheap and easy -removal of isolated plants Cons: -ensure all above ground foliage is removed -not effective control method for large infestations
Mowing	-this is a late season treatment -specific months not specified in literature	-Before spiny seed head develops	Pros: -control of light infestations -inexpensive Cons: -risk of encouraging current population growth -effectivness depends on shape and structure of plant -does not control YST
Tillage	-end of rainy season or when ground is wet	Before viable seed are produced	Pros: -control of high YST infestations Cons: -non-selective -can increase soil erosion -encourage other noxious weed growth
Herbicides	See Additional Chart	***********************	***************************
Prescribed Burns	-End of June to Early July	-early bloom to late bloom	Pros: -encourage native plant growth -kill other invasives Cons: -escape of fire -effect on air quality -should not be used in conjunction with biological control agents
Re-vegetation	-late winter to early spring -actual timing will vary with species used	-not specified in liteature	Pros: -long term control method once established Cons: -expensive -success is difficult to foresee

Biological Control	See Additional Chart	**************************	***************************

Potential Herbicides (DiTomaso, 2006)

Commercial Name (*active ingredient*)	**Time of Application and most effective concentration**	**Best Controls this Stage of Growth**	**Pros:**	**Cons:**
Transline (*Clopyralid)*	-January to March -4-10 onces per acre	-seedlings and rosettes	-pre and post emergent -effective herbicide at low concentrations (4-10 oz per acre) -slowly absorbed into soil -does not volatilize -highly selective (doesn't injure grasses and most broadleaf species)	-slow-acting compound, may take longer than two months to control YST -injures or kills most species in Fabaceae and Asteraceae
Round-up (*Glyphosate)*	-1lb a.e. (acid equivalent) per acre	-bolting, spiny, early flowering stages	-postemergent -no soil activity -good for spot treatments	-non-selective -not effective for broadcast applications
Telar(*Chloros-ulfuron)*	-late winter to early spring -1-2 onces per acre	-not specified in literature	-pre-emergent -does not injure most grasses -combine with 2,4-D for best results -can control other invasive weeds	-not registered in the state of CA -not often used for YST control
Tordon (*Picloram*)	-late winter to early spring -.25lb-.375 lbs a.e./acre	-rosette to bud formation	-post and pre emergent control -specified concentration can control for 2-3 yrs	-not registered in the state of CA -residues longer in the soil (2< yrs) -can kill very young grass seedlings
Weedar, Weedone (*2,4-D*)	-.5-.75 lb a.e. per acre	-rosette	-Post-emgerent control -no to little soil activity	-requires permit for use -herbicide drift is common -not good for broadcast applications

Biological Control

The use of biological control insects reduces the overall seed production of YST.

Insect Common Name (Scientific Name)	Impacts other plant species	Effect of insect on YST growth
Seed-Head Weevil (Banasternus orientalis)	Yes. -Purple starthistle (*Centaurea calcitrapa)* (Olind, 2000)	-feed on receptacle tissue and developing seed (Olind, 2000) -most effective during larval stage
Seed-Head Fly (Urophora sirunaseva)	No	-eats most developing seeds inside the flower head (Wilson et. al 2003) -most effective during the larval stage (Olind, 2000)
Hairy Weevil (Eustenopus villosus)	No	-feeds on insides of flower head thereby destroying seeds and flower head -larval and adult stages attack YST (SCNWCB, 2006)
False-Peacock Fly (Chaetorellia succinea)	No	-feed on ovaries and developing seed (Wilson et. al) -most effective during the larval stage

PART THREE:

Controlling and preventing the establishment of new YST infestations is a win-win situation because most exotic management plans utilize the same control methods used for YST management. The control of YST will help encourage native plant growth which is desired by the Putah Creek Reserve.

- ❖ Controlling the spread of YST will foster current native plant growth which may indirectly foster animal habitats
- ❖ Controlling YST may also control other exotics such as Ripgut Brome and Milk Thistle

However, there will be tradeoffs between controlling YST and managing multiple goals because some control methods may be detrimental to achieving other goals. The following are points of interest or concern.

- ❖ In north upper pond, the presence of exotics may also indicate the presence of YST. As a result, herbicide application must be carefully selected or not used at all as this area is near water and important animal habitats (garter snake, kite)
- ❖ On the east side near the landfill, grading and terracing the bank may promote the germination and growth of new YST populations. So this area should be monitored for emerging infestations
- ❖ In the lower south pond, there is potential for the emergence of new YST infestations
- ❖ The establishment of a riparian area and streams, means herbicides should not be used in this area to prevent contamination of waterways
- ❖ During the ENH 160 lab, I saw quite a few sporadic areas with YST growth in the upland areas. Since there is exotics and natives mixed in, the on-site managers must determine whether or not a prescribed burn or spot herbicide application would be beneficial
- ❖ Since the active management of forbs requires some disturbances, YST may be able to compete with the forbs and invade this area. Monitor for new plants and/or infestations
- ❖ Prescribed burning is non-selective and will destroy current native growth
- ❖ Tillage or grading could encourage YST and exotic weed growth

Factors limiting YST control

- ❖ Proximity of infested area near waterways, this will limit what herbicide is used and how it is applied
- ❖ Proximity to animal habitat: influences herbicide selection and grazers/grazing regimes

Management Plans

A. Ripgut Brome: burn in late march to april before the seeds are mature, mow but not graze

Pros: Mowing coincides with YST goals

Cons: suggested burning regime is earlier than the YST burning regime

B. Mustards: burn, mow in april (in combination with solarization), no grazing

Pros: Can be burned and mowed

Cons: Grazing is not used

C. Ryegrass: dry season burning next year, early season grazing, or mow instead of graze

Pros: This plan may coincide with YST goal well.

D. Star thistle: burn in late june to early july, graze with goats

E. Milk thistle: burn in early spring

Cons: Again, burning is earlier than YST burning regime

F. Blackberry: burn in spring, graze with goats

Pros: Grazing with goats is an effective control measure for both blackberry and YST

Of the group scenarios, ryegrass and milk thistle management plans seem to coincide with YST management. The best case scenario is that most multiple goals are achieved and the infested area is restored to the original landscape. The worst case scenario is that none of the multiple goals are achieved and YST control procedures spur excessive YST growth.

Revised Plans and Goals

Meeting the multiple goals of other management plans while reducing YST infestations, will require proper research and timing. Minimizing negative interactions and trade-offs is very important. Based on in-class discussions, I believe that exotic species management will be an effective control of YST. Since there are a few constraints such as the extensive waterways and the encouragement of vital animal populations, herbicide applications will have to be used sparingly on the site. Also, determining the most effective burning regime will require proper timing as it appears other exotics respond to early spring burns. While some management plans do not use grazers, many others do. Depending on the time of year the grazers are used, cows, sheep, and goats are effective grazers of YST. However, blackberry management may require the use of goats.

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ENH 160
Spring ‘09

Iris pseudacorus; Yellow flag iris

Background

Iris pseudacorus, also known as yellow flag iris, yellow flag, or water flag, is a perennial emergent wetland plant with beautiful showy yellow flowers. It grows up to 5 feet tall and is found along freshwater wetlands, fens, lake shores, stream banks, and on the edges of ponds. Flowers bloom from April to August. *I. pseudacorus* is native to Europe and the British Isles, North Africa, and the Mediterranean region. *I. pseudacorus* was brought to the U.S. as an ornamental plant in the early 1900’s and it is still being sold in nurseries and over the internet (Center for Aquatic and Invasive Plants). Furthermore, *I. pseudacorus* was also introduced for its use for erosion control and for sewage treatments cells. They are able to remove heavy metals such as copper and iron from storm water, industrial wastewater, agriculture, food waste, mining, and many more, that will otherwise run downstream into our reservoirs or seep into groundwater. *I. pseudacorus* can tolerate high soil acidity (ph 3.6-7.7) and has a high nitrogen requirement which is readily available in the types of wastewater mentioned above (Calheiros, 2007).

Problems with *I. pseudacorus*

Like many introduced species, they cause a significant amount of problems to the current habitats it establishes. The yellow flag iris is a fast growing and fast spreading weed (The Nature Conservancy) and therefore, it is very important to prevent new infestations to other sites and to also eradicate current populations. These goals are very important because *I. pseudacorus* can out compete native species in their natural habitat by transforming a landscape into monotypic stands along stream banks. It spreads by rhizomes and creates mats that can prevent native seeds from establishing. These mats can also compact the soil and trap sediments, therefore increase the elevation of the area, which creates a drier habitat that will not support many native riparian and wetland species such as cattails (Montana Department of Fish, Wildlife, and Parks). The yellow flag iris is difficult to control because the rhizomes that break off are able to form new plants and drift to other habitats. Even rhizomes that dry out are still viable and can invade an area when re-moistened (Calheiros, 2007). Other negative impacts include the seeds clogging small streams and irrigation systems. The plant also contains large amounts of glycosides that is a poisonous irritant to humans and can cause gastroenteritis in cattle (Sutherland, 1990).

Policy and Funding

The yellow flag iris is only state listed as a weed in Connecticut (banned), Massachusetts (prohibited) , Montana (category 3 noxious weed), New Hampshire (prohibited), Oregon (B designated weed quarantine), and Washington (class C noxious weed). It is distributed all over the U.S., especially along the east side of the country. It is also listed on the USDA Natural Resources Conservation Service Invasive Plants list and on the exotic plant restoration list of California exotic restoration plant council (USDA). B class is classified as " 'B – Eradication, containment, control or other holding action at the discretion of the commissioner'. And class C is– 'State endorsed holding action and eradication only when found in a nursery; action to retard spread outside of nurseries at the discretion of the commissioner; reject only when found in a crop seed for planting or at the discretion of the commissioner' " (California Department of Food and Agriculture).

State listed weeds provide opportunities for the target goals mentioned above by yielding attention to other less impacted areas that the yellow flag iris has infested. This also provides a window of opportunity for studies to be done alluding to management control for the weed for other states. Although the yellow flag iris is not listed as a weed in many states, such as California, it is still noticed as a weed and may not receive much attention until it becomes a bigger problem. This is the only constraint with funding. Grants are usually issued when weeds are noxious and have a huge impact on the environment; where the best time to take action on a weed is in small populations. It may be more difficult to deal with dense colonies.

Management Techniques

There is very little information available on how to prevent the spread of the iris effectively. However, there are some possible management techniques to prevent the spread of the weed. Some control options include manual, mechanical, cultural, biological, and chemical techniques (The Nature Conservancy).

The manual approach includes actually going underwater and removing the rhizomes individually. In an aquatic weeds management report, an underwater cutting technique was done in a wetland in King County, Washington. Random 1 square meter plots were chosen for cutting in spring before flowering, mid-summer before seed drop, and in fall at the start of senescence. The results showed that cutting in the spring before the plant flowers seems to be most effective. After a year of the treatment, the stem density of *I. pseudacorus* was reduced from 85 to 36 mean number of stems per unit area

(Simon, 2008). This is logical since the flowers have not been produced, there is no chance for seeds to even occur, whereas, there is a chance for viable seeds to form during the mid-summer and fall.

On the other hand, this method has to be carefully done because the yellow flag iris spreads by rhizomes, so it can easily re-sprout after a disturbance. The whole rhizome must be removed completely in order for underground cuttings to be effective. In this experiment, the plots were only 1 square meter and were surrounded by irises that were not cut; therefore, encroachment of the cut area was evident. Therefore, this method will only work in very small stands of the weedy species with complete removal of rhizomes.

Another manual approach was used to help eradicate the yellow flag iris at Buena Creek, Washington. At this site, an experiment was done to see how effective it would be by cutting the plants and covering the area with four different materials (landscape fabric, tarp, black plastic and clear plastic) in the early spring. This treatment was done for approximately one year and the results showed that the tarp was most effective. The tarp was removed after two years, and no irises were grown under it. All the other coverings had irises emerging under the fabrics and plastics (Simon, 2008). Again, just like in the other experiment mentioned previously, encroachment was evident since the plots were done with surrounding stands of the plants. Therefore, this method will only work in very small stands with complete rhizome removal to prevent it from re-sprouting.

Huge machines can be used to destroy the bulbs and roots. It is best to use this method before seeds can be dispersed (Simon, 2008). Burning used as a control method is not recommended. Studies have shown that burning allows seeds to germinate and grow very well after a fire. Also, plants tend to re-sprout from rhizomes after a burn (Weed Control Board). Moreover, the timing of when to burn and getting permits to burn are also very tedious.

Another method is the cultural control where knowledge of this noxious weed is being spread to nurseries and civilians who may have this species growing in there yard. The general recommendation is to remove it and replant with native species. Unfortunately, the yellow flag iris is still being sold over the internet as an ornamental plant (Integrated Pest Management Prescription, Thurston County).

Moreover, chemical uses to control the yellow flag iris have been effective. The problems with herbicide use are that there are problems with polluting water. Also, there are many problems with the use of herbicides where you may have grazers or other plants that cannot tolerate the chemicals. For the yellow flag iris, only non-selective herbicides are useful. Since this species is a monocot, the non-selective herbicide may kill surrounding plants such as dicots, since non-selective herbicides are not species specific (Department of Natural Resources). Some non-selective herbicides that controlled the yellow flag iris are Glyphosate and Imazapyr. The problem with these herbicides are run off and killing surrounding species. Also, the herbicides require the addition of an approved surfactant (Weed Control Board). Surfactants act like a wetting agent that lowers the surface tension of a liquid allowing easier spreading.

One study tested both of the herbicides in spring and in the fall. The results showed that the Imazapyr was a better herbicide to use overall in the spring and in the fall. Also, fall herbicide application was more effective than the spring treatments but just by a very small amount (93% in fall and 87% in spring average weed control after treatment) (Simon, 2008). The use of both herbicides was more effective than just using one of the herbicides a lone in suppressing the growth of the yellow flag iris (Simon, 2008). This study was unclear as to how the herbicides were applied. However, according to Thurston's County pesticide review process, spot applications and stem injections are recommended for controlling the yellow flag iris. Spot applications are when the herbicide is applied directly onto the plats and not on the surrounding plants. Hollow stem injection is when the herbicide is injected directly into the stem of the plant (Integrated Pest Management Prescription, Thurston County).

Reducing the spread of the yellow flag iris is difficult because there are not really any biotic controls that can help disclose this species. Since the yellow flag iris is poisonous, cattle or sheep will not eat it. The seeds are not eaten by any birds. However, there are some invertebrates, pest, pathogens, and fungi that may be possible control agents, but further investigation needs to be done (Sutherland, 1990).

Other main factors affecting the goal are the spatial scales. Most of the non-herbicide control is very tedious and tends to only work for very small stands. If the stands are too dense, the use of herbicides is the only alternative to control the noxious weed. Furthermore, the changing climate is another factor that can affect the success of the goals. It is questionable as to whether the methods that are being used currently should be the right direction we should be heading. It is unclear as to whether if actions should be taken immediately or should one wait for more recent data as to what the actual effects will occur due to the changing climate. Or will it be too late? This also leads to gaps in our knowledge that limit effective restoration planning.

Goals and Management Plans

The key to a successful and cost-effective control of *I. pseudacorus* is to prevent it from establishing new areas and to control populations that are still small and manageable. Since *I. pseudacorus* grows so vigorously by reproducing vegetatively and sexually, it is difficult to manage once it is established; therefore, it must be controlled during the early stages of invasion (Sodja 1993). For this project, I would like to propose an integrated management approach, where two control methods are combined, such as mowing/cutting of the iris stems (depending on the size of the site), than inundating the species with water for a period of time, followed by covering the area with tarp. The study will take place at the Putah Creek Reserve (Figure 1, 2a and 2b). The site will be closely monitored for effectiveness of the treatment.

Some research questions that can be answered in this restoration project

-What is the best non-chemical method for controlling *I. pseudacorus*?

-By comparing densities of pre and post treatment, we can know the success or failure rate of controlling *I. pseudacorus*.

-How long does post restoration monitoring have to occur in order for the species to be completely eradicated from a site?

- We can understand how competition and shading affect growth, survival, and reproduction.

Since this weedy species is able to spread vegetatively, it is difficult to control once it is established. Thus, short term goals will most likely lead to long term goals as well. Short term goals include targeting small densities and detecting the species spread at its early stages of invasion. Since small rhizome fragments can easily resprout, monitoring the site for several years may be mandatory.

Long term goals include preventing re-invasion of *I. pseudacorus*. This can be done by monitoring the site every year or every few years depending on the treatment applied to identify new infestations as well as regrowth. Since *I. pseudacorus* has a high reproductive vigor, few pest and predators, and can adapt to different environments, the potential for successful management is not so high unless if controlled in small densities and follow-up treatments can occur. For example, if herbicide treatment is used, some trade-offs would include the senesce of the plant, however, contamination in the pond may worsen the water quality (Integrated Pest Management).

Restoration Plan

In any setting *I. pseudacorus* is very difficult to control; it responds positively to fire and there are no biological control agents available for the control of the weed (The Nature Conservancy). Certain treatment options are site and density dependent. The study will be done on less than 1 acre stand of *I. pseudacorus* on the Putah Creek Riparian Reserve pond in Davis, Ca. Water can be controlled with the near by aquaculture. The yellow flag iris will be removed in the month of January to March before the blooming season will occur which is between April to August.

A method that may be feasible is to cut the stems of the yellow flag iris and inundate it with water for a period of time (Approximately 1 year). This has been a successful method used to control invasive native cattail species (*typha* ssp.). Cutting and reflooding has shown that injured cattails had poor recoveries (Afelbaum et. al.). When the leaf is cut under water, it breaks the aerenchyma as well, which is the cell in the leaves that supply oxygen to the rhizome. Thus, high water levels extend the amount of time during which the plant needs to convert the stored starches to sugars for shoot growth (Sojda 1993). Therefore, a similar technique may be used for *I. pseudacorus.*

The plants in the plot area will be cut with a line trimmer (John Deer XTl120LE) under water to limit air supply to the rhizomes. Plot sizes will be 10 x 8 feet in size. The process will be done in small sections to make sure all stems are cut. Water level will be a foot above the cut stem, to make sure it's completely submerged in the water (Murkin 1980). Since the yellow flag iris grows near ponds or wetlands, water levels can be controlled by a surface irrigation system if water levels vary. If one does not exist, it can easily be done by burrowing ditches or using pvc-pipes so water may flow through (UCDavis, HYD 110). Other studies have shown that when the plant is under complete submersion, there was no growth detected but the rhizomes were able to survive over 8 weeks of continuous flooding (Schleuter). Therefore, the yellow flag iris will be inundated for a year to make sure the rhizomes did not spread and have completely senesce.

After the stems have been cut and flooded in water, I will only use the tarp to cover the plots. The tarp will be anchored along the edges with concrete bricks for a year so that light will not be available for the plant to photosynthesize (Simon, 2008). This integrated management approach should prove to be most effective in eradicating and spreading the yellow flag iris. Moreover, caution must be taken when using this technique because the leaves and rhizomes produce a resin that causes skin irritation to humans (Center for aquatic and invasive species). Gloves and clothing that covers all potential contact of the yellow flag iris to the skin can be a solution to prevent irritation.

Other risks and uncertainties include excessive digging in the soil can cause erosion, and again will fragment rhizomes, and promote germination of *I. pseudacorus* and potentially, other undesirable species from the seed bank. So care must be taken using these methods. Thus, post management monitoring is the key to a successful restoration plan.

Post restoration monitoring is crucial in making sure rhizomes that may have re-sprouted do not have a chance to fully establish. After treatments have been completed in a year, re-establishing native plant species is very important to prevent erosion and to provide habitat for animals such as the garter snake or turtles. Thus, an open native grassland habitat will be established after treatments are done to pond one. Some native grasses that can be planted are creeping wildrye (*Leymus triticoides*), Fescue (*Vulpia microstachys*), California brome (*Bromus carinatus*), and Meadow Barley (*Hordeun brachyantherum*) (California native grass association). These species will be native cultivars by purchasing certified seeds from native plant nurseries. See appendix 1 for native nursery locations in or near Davis, Ca (California Native Plant Society).

Planting of the grass seeds will take place in the Fall between August and September. The temperatures will be a bit cooler so the seeds will not be scorched from the heat. Also, this will give the seed plenty of time to establish before winter. Since the site is small, grass drills and seeders are not necessary. The seeds can just be planted on the soil bed and tilled (Seedland).

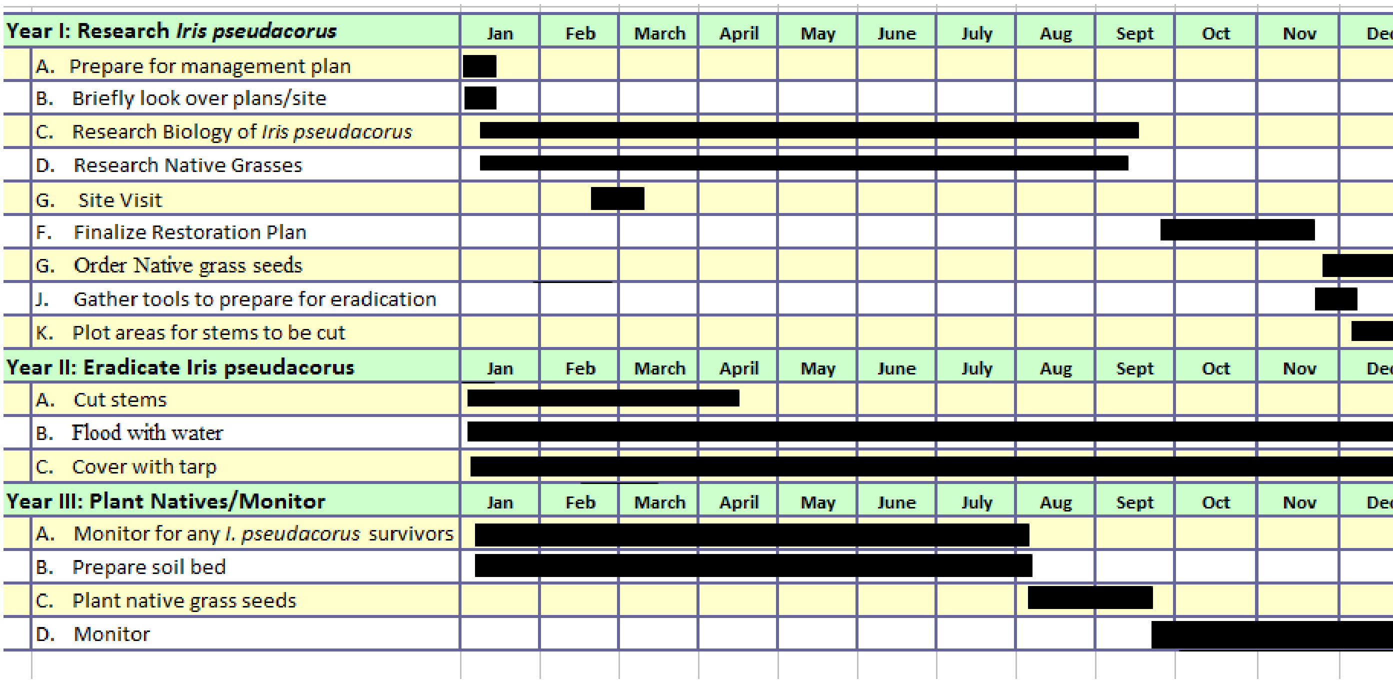
The site will than be managed after seeding to make sure the grasses establish and monitored for any new weeds or for the yellow flag iris.

A lot is known about the biology and growth of the yellow flag iris, unfortunately, very little research has been done or even known as to how to effectively control it. Therefore, in order to improve the restoration plan, more information is needed on the mechanisms of the yellow flag iris invasion and spread in different community types. Also, we need to understand how competition and shading affect growth, survival, and reproduction. And, which, if any insects or pathogens control the yellow flag iris abundance in its native range (The Nature Conservancy).

Managing Multiple Goals

As a class, multiple goals were decided upon the Putah Creek Riparian Reserve such as building a retention pond near the riparian/creek that will meander. Other goals include creating a grassland habitat once the yellow flag iris has been eradicated successfully for the garter snake and other animal species to use. This would be a great post re-vegetation for my restoration plan. More goals are to create seasonal wetlands in some of the basins and eradicating the weeds in the uplands by solarization, grazing, or apply fire in late March early April. The only drawback with the goals is with fire being used to die back some of the weedy species since the yellow flag iris responds positively to fire. The yellow flag iris only occurs in the pond areas and not the basins and so care must be taken to make sure the fire does not blow over to the ponds from the uplands. Also, seeds of the iris can be easily blown over to the basins and may quickly establish after the fire.

Project Schedule



Budget

line trimmer- John Deer (3)	$1,000
tarp	$1,000
PVC pipes (if necessary)	$100
tractor (if necessary) rent	$1,000
labor	variable $10,000-$50,000
tools (shovels/gloves etc)	$500-$1,000
native seeds	$500
soil	$50
pumps	$500
misc	10,000
Total	$100,150

Appendix 1

Albright Seed Company
P.O. Box 1275
Carpinteria, CA 93014-1275
805 / 684-0436
www.albrightseed.com
Bulk sales grass, wildflower, shrub & tree seed, 50% native; $25 minimum order.

Appleton Forestry Nursery
1369 Tilton Road
Sebastopol, CA 95472
707 / 823-3776
Container trees & shrubs, contract collect & grow, wholesale & retail. Call ahead.

Agua Fria Nursery
1409 Agua Fria Street
Santa Fe, NM 87501
505 / 983-4831
Mail order retail plants, wide selection, uncommon penstemons, many California-collected natives.

Bay Natives
375 Alabama St. #440
San Francisco, CA 94110
Tel. 415 / 287-6755
Fax 415 / 285-2240
www.baynatives.com
Ecommerce local native plants suited to SF Bay Area gardens and landscapes.

Baylands Nursery
965 Weeks Street
East Palo Alto, CA 94303
www.baylands.com
Wholesale & retail plants, about one-third native.

Bayview Gardens
1201 Bay Street
Santa Cruz, CA 95060
Mail order iris. Joe Chio Pacific Coast Hybrids.

Berkeley Horticultural Nursery
1310 McGee Avenue
Berkeley, CA 94703
510 / 526-4704www.berkeleyhort.com
Retail plants - one section devoted to natives.

Literature Cited

Calheiros, S.C.C., Rangel, O.S.S.A., Castro, P. (2007). Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. Water res. 41: 1790-1798.

Murkin, H.R. (1980). Early Spring cutting to control cattail in Northern Marsh. Wild. Soc. Bull. 8: 254-256.

Pathikonda, S., Ackleh, A.S., Hasenstein, K.H., and Mopper, S. (2008). Invasion, disturbance, and competition: Modeling the fate of coastal plant populations. Conser. Boil. 23: 164-173.

Simon, B. (2008). Aquatic Weeds Management Fund Final Report. Washington Department of Agriculture.

Sodja, R.S. (1993). WaterFowl Management Handbook. U.S. Fish and Wildlife Service.

Sutherland, W.J. (1990). Iris Pseudacorus L. Jrnl. Of ecol. 78: 833-848.

Integrated Pest Management Prescription. Thurston County Public Health and Social Services.
Thurston County Public Health & Social Services
2000 Lakeridge Drive SW
Olympia WA 98502
Phone: 360-754- 4111
T.D.D. 360-754-2933

Cowlitz County-Yello flag iris factsheet
Cowlitz County Noxious
Weed Control Board
207 Fourth Avenue North
Kelso, WA 98626
Tel. (360)577-3030
Fax (360)636-0845

California native grass association

Department of Natural Resources and Parks water and land resources division. Noxious weeds control program. Best management practices- Yellow flag iris. January 2007. www.kingcounty.gov/weeds

Center for aquatic and invasive plants. University of Florida, IFAS. http://aquat1.ifas.ufl.edu/node/205

USDA-Plants Profile

http://plants.usda.gov/java/profile?symbol=IRPS

California Department of Food and Agriculture
http://www.cdfa.ca.gov/phpps/ipc/weedinfo/winfo_list-pestrating.htm

California Native Plant Society
http://www.cnps.org/cnps/horticulture/nurseries.php

Wildlife species

Katelyn Raby
ENH 160
6/4/09

Western Pond Turtle Restoration

“Conservation” is a buzz word that almost everyone has heard at least once in the past week. When humans speak of “conservation,” there is a bias towards big and cute fauna. The common citizen is not aware of the eminent extinction of many nematode, amphibian, and reptile species. The Western Pond turtle is an example of a species that is not generally thought of as “endearing,” but has become increasingly more scarce. The broad goal of this restoration project is to establish the Western pond turtle into the study site and to maintain a stable population over time.

Promoting viable populations of the Western pond turtle is not what most people consider an “interesting” conservation goal. Turtles are, however, an ecologically important species that serve as food for higher trophic levels, such as raccoons, coyotes, largemouth bass, etc. (Bender 2009). They are also important predators on algae, snails, crayfish, isopods, insects, frogs, etc. (Lovich 2009). A pond that does not have turtles and other algae consumers soon becomes filled with a thick green scum that lowers the oxygen content of the water to a point that it becomes uninhabitable to most species. The Western pond turtle also has value purely for biodiversity conservation because it is the only native freshwater turtle in California (Bender 2009). Recent molecular analysis also has conclusive evidence that the Western pond turtle *(E. marmorata*) title actually includes four distinct phylogenetic taxa within *E. marmorata* that should be conserved to promote biodiversity (Spinks and Shaffer 2005).

Populations of the Western pond turtle have been declining throughout its range. The species ranges from extreme western Washington down to northern Baja, California. In 1992, the IUCN rejected the petition by the Department of Fish and Game for the turtle to be put on the Endangered Species List (Lovich 2009), but it is considered state endangered in Washington where populations have dropped to below 200 individuals (Bender 2009). They are also listed as state threatened in Oregon and in California they are a species of special concern (Spinks et al 2003). The species has been experiencing range-wide rapid decline since around the 1970s (Lovich 2009). Even informal studies here at the UC Davis arboretum have noticed declining populations since around the 1980s (Spinks et al 2003).

There are not that many national or local laws that deal with freshwater turtles and much less likely the Western pond turtle in specific. It is illegal to trap turtles without a permit, but this particular species is usually not considered a food item that is captured by trapping (TCF 2009). The California Department of Fish and Game does impose a $500 fine for the collection of the Western pond turtle without a permit. Imposing this regulation is difficult considering an official must be at the right place at the right time to be able to fine a perpetrator.

No restoration project can be completed out of just the goodness of people's hearts, there must be substantial funding involved. Luckily, freshwater turtles do have several non-profit groups that support and fund turtle restoration. The Turtle Conservation Fund is one such group that funds conservation biology research and field surveys of freshwater turtles. The IUCN/SSC has a division called the Tortoise and Freshwater Turtle Specialist group that has recently published a book outlining specific conservation methods and goals. The California Turtle and Tortoise Club is also very active raising funds through the community to fund various restoration projects benefiting turtles.

In order to initiate a conservation program for Western pond turtles at this site it is necessary to know the main factors influencing the population negatively. Current problems for these turtles that have been identified are: urbanization and agricultural development, livestock grazing, gold and gravel mining, dams, and timber operations (Reese and Welsh 1998). Some of the more important aspects of urbanization are that dams and water diversions change the water velocities and temperatures, and riparian vegetation structure for pond turtles (Reese and Welsh 1998). It also has recently been suggested that competition and predation from non-natives may play an important role in conservation (Spinks et al 2003).

Western pond turtles are considered generalists in that they can be found in streams, ponds, rivers, and even estuarine conditions; however, they still have many biological constraints that can make conservation difficult (Reese and Welsh 1998). Studies have shown that these turtles prefer an aquatic habitat that has low water velocities, deeper water pools, underwater hiding places, and some vegetation canopy. Turtles are poor swimmers and therefore rely on cryptic coloration and refugia underwater to protect themselves from predators. Adults also use deep pools for foraging for food and the ideal depth should be about six feet; however, juveniles are too small to forage in deep water and require shallow waters about a foot deep (OFW 2009). Being ectotherms means that turtles regulate their body temperature using external heating sources. A very cold stream means that turtles must spend more time basking to regulate their core temperatures and less time foraging and reproducing. From a conservation standpoint these characteristics must be noted because human altered waterways often have faster flows which means less debris underwater and lower water temperatures (Reese and Welsh 1998). Emergent logs are often removed in flood control areas as well (Spinks et al 2003). Recently it has also been noted that Western pond turtles compete with red-eared sliders for the few available basking sites. Red-eared sliders have a larger adult size and have been observed to win aggressive encounters over basking sites (Spinks et al 2003). Temperature also has important effects on turtle reproductive biology. Since turtles have temperature dependent sex determination, the incubation temperature is a critical constraint. The warmer the air the more females are produced and the colder the air the males are produced. The temperature range that produces an equal sex ratio is between eighty-two and eight-four degrees Fahrenheit (Bender 2009). That is an extremely narrow range to manage for. Female turtles, on average, excavate nests about forty-five meters from the water source (Spinks et al 2003) and lay their eggs in June or July (OFW 2009). They prefer well-drained sandy-clay soils with mostly short and sparse grassy vegetation because the eggs need direct sunlight for incubation (Spinks et al 2003). Studies of pond turtles in Oregon show that the hatchlings emerge in the early fall (OFW 2009). However, these are generalizations and in actuality there are many more questions to be answered about the Western pond turtle reproductive biology. For example, why the range of distance from the water for nesting varies considerably, the reasons for choosing upland locations, if the eggs overwinter in the nests and when exactly they emerge (Rathburn et al 1992). Considering that males have a home range size of about 2.42 acres and females also travel for nesting, it is obvious the turtles require a large buffer zone around the habitat (Lovich 2009).

In order to manage this species it is also important to consider the temporal scale of their reproductive behavior. Like many other turtles and tortoises, the Western pond turtle is long-lived (up to about 60 years) with high adult survivorship and high juvenile mortality. This means that a Western pond turtle does not even begin to breed until about ten to fourteen years of age (Bender 2009). Thus it is critical to consider the reasons for juvenile mortality so that they can live until breeding age. The main predators on juveniles are the red-eared slider, american bullfrogs, largemouth bass, and rats. All of these species are exotics that would not normally be considered threats (Bender 2009). Rats are especially an issue in urban waterways because rats thrive in human altered environments (Spinks et al 2003). Adult mortality also has risen due to the introduction of exotic turtle species. The red-eared slider introduced a respiratory disease that wiped out several populations of Western pond turtles in Washington (Spinks et al 2003). Exotic species should be considered for removal if the pond turtle is to survive.

Since the Western pond turtle is not so cuddly and cute, and has not been declared officially endangered by the IUCN, there have not been too many projects to restore populations to historic numbers. Thus there are not too many studies to assess successes and failures of. The Oakland Zoo has recently teamed up with Sonoma State and the San Francisco Zoo in order to form a working coalition to come up with conservation plans for the turtle. The idea is to raise hatchlings for about ten months and then release them into the wild. This way their shell has hardened and they are big enough to escape their most popular predators. This method also ensures equal sex ratios by using temperature-controlled incubators. Results are not available yet for the success of this program (Bender 2009).

The most comprehensive study of Western pond turtles in urban environments with conclusive results actually comes from right here at UC Davis. Researchers studied the arboretum waterway that runs through campus for six years starting in 1996. The project began when the researchers noticed a forty percent population decline of the turtle since 1993. The study found that indeed the turtles are in decline on the campus since they only captured one hatchling and eight juveniles since 1996. This works out to be 1.5 natural recruitments per a year, which is not enough to sustain the population. This observation of demographics led to the conclusion that there must not be suitable nesting habitat and an experiment in “head-started” turtles. Head-started turtles are reared in captivity from the egg and then released into the wild again. Researchers reared thirty-one such turtles and during the six year studied consistently recaptured twenty-four of these turtles. This indicates that head-starting is certainly a viable option for reestablishing population numbers; however, it is limited because it does not address the reasons for the decline and requires constant management (Spinks et al 2003).

The Western pond turtle does not have much choice but to live in an urban environment. Most populations of the turtle are near urban areas in manmade waterways because of urban sprawl. This actually may be a good refuge for the species because of increased flow of nutrients into the manmade waterways and it can provide a showcase to the public to gain awareness and appreciation for their only native turtle. Urban waterways can be managed carefully for Western pond turtles to reduce the usual lack of vegetation and basking sites associated with human constructed canals. The habitat must be spatially managed to include their requirements for nesting. There also should be non-irrigated regions nearby for nesting because the hard shell of the egg cannot expand with excess water and will crack when a soil is too moist. The literature, however, does not contain a threshold value for the how moist the soil can be. Humans can also provide basking areas by anchoring logs into the pond. Head-starting should be considered in any conservation program and also the area must be managed for non-native turtle species. Extensive trapping and public awareness to not leave unwanted exotic pet turtles in ponds could help to reduce the problem. Management for the Western pond turtle will be time-consuming in the beginning, but will restore California's only native freshwater turtle.

Management Plan:

The western pond turtle is a generalist and so it is hard to believe that it could be in such severe decline. These turtles can live in stagnant or flowing water and their prey sources are so varied that that is not a constraint either (Reese and Welsh 1998; Lovich 2009). The main constraints of western pond turtles are having proper nesting and basking habitat. Elimination of exotics (namely the red-eared slider and American bullfrog) and headstarting turtles are recommended actions to facilitate population establishment. The main goals of this restoration project include:

--Addition of debris underwater for refuge and emergent logs for basking all year long

--Reconstruct basins to reach a depth of six feet with shallows a foot deep

--Eliminate red-eared sliders present before introduction of pond turtles

--Establish a buffer zone of at least fifty meters surrounding the basin that is cleared of woody species and is not mowed, grazed or irrigated between June and early fall

--Headstart turtle eggs for ten months before release

--Monitor turtles for ten years

All of these goals are very feasible to accomplish without much monetary commitment. Most of these goals also will provide benefits to the other species involved. Providing a buffer zone free of woody forbs will help provide a suitable habitat for those grassland species that do not grow well shade. The goals also offer protection to the other wildlife species of concern. The giant garter snake also needs basking sites and emergent vegetation or debris for escape from predators and to promote a prey base. The western pond turtle uses upland grassy areas for nesting summer through early fall, but it also requires this habitat because it hibernates in burrows during winter, as does the giant garter snake (Ashton et al 2009). Having a buffer zone that is not grazed during summer also would provide perennial grassland habitat for the vole populations that the white-tailed kite is dependent on. Even though the restoration goals for the western pond turtle will benefit other wildlife, they may have tradeoffs with plant species. Since no grazing or mowing should be done summer through fall to protect nesting habitat, this could be a potential problem for the grass species that need periodic grazing or mowing to keep out exotics and to encourage growth. Another tradeoff that would come with turtle restoration is that prescribed fire is highly unadvisable all year long because it will kill turtles overwintering in burrows from about September to March and hatchlings in the nest from early summer to emergence late the following spring (Ashton et al 2009; OFW

2009). Fire suppression is a goal of the project, however, many species are adapted to periodic burning for increased growth and exotic eliminations.

The first goal of the project is to provide debris to bask and hide under. This a simple goal that would involve anchoring logs in the ponds to provide constant air basking sites (Reese and Welsh 1998). Woody debris cleared from the buffer zone could be thrown into the basins to provide underwater refuge. Basking is a year-round requirement and the presence of sufficient debris should be carefully monitored until the ecosystem establishes. The second goal is make sure that the ponds have deep pools and shallows (OFW 2009). This may not be an issue if the basins already have this configuration, but a backhoe may be necessary to regrade the pools if the criteria are not met. The third goal is to eliminate any red-eared sliders that are present on the site before introduction of the pond turtle since they prey on juveniles and compete with adults (Spinks et al 2003). This can be done through trapping followed by euthanasia. Monitoring using basking traps should be done throughout the ten year period to ensure that red-eared sliders have not established again at the site. Basking traps have been proven to be effective in turtle capture when baited with dead minnows (OFW 2009), however, there is always some uncertainty when using a trapping program. Some issues can be trap-shyness of red-eared sliders so that they will not enter traps, or placement of traps in locations that the red-eared slider does not use (habitat preferences can be difficult to establish).

The buffer zone of fifty meters is probably going to be the most difficult goal to accomplish due to the other species need for mowing and grazing. Clearing woody species by manual methods is simple in practice, but monitoring should be done in subsequent years during the spring when seeds are being dispersed to ensure that the grassland establishment has prevented forb reestablishment. The critical part of this goal is that grazing, mowing, and irrigation can absolutely not occur between June (when the eggs are laid) and the subsequent spring (when hatchlings emerge from overwintering) or else the eggs will be cracked from excess moisture or may be trampled by grazers and lawn mowers (Spinks et al 2003). Prescribed burning should not occur at the site at all because it will kill all turtle life stages, but natural fires are going to occur once in awhile and should not be immediately suppressed so that the native grasses will be encouraged to grow.

The next goal is to use headstarting to establish a population. The origin of the eggs is not of great importance for genetic purity because only western pond turtles in the northern part of the range in Washington are of a different subspecies; however, obtaining eggs from surrounding areas may be beneficial due to local adaptations. An uncertainty associated with this goal is that it is unknown how many eggs should be headstarted so that a steady population can be established. Under optimal conditions in Oregon, studies show that there are turtle densities of about 202/acre (Lovich 2009). The first basin at the site is 2.3 acres and if we wanted to establish normal densities we would then need to have 464 turtles on site. Hatchling survivorship is generally around seventy percent which would mean we need to raise 664 turtles to get 202 turtles per an acre at this site. These calculations are probably too high since the densities in Oregon may not apply to California and more turtles are present than necessary to simply maintain a population. Once the desired density of turtles is settled upon, caring for the eggs is fairly simple and inexpensive. An incubator is required that can keep the eggs at eighty-two to eighty-four degrees to ensure equal sex ratios (Bender 2009). After the eggs have hatched, care should be continued for ten months before release, but hatchlings are precocial which means that they can take care of themselves independently after birth so that constant care is not required from humans. Headstarting should continue until a viable population has been established.

The last goal is a ten-year monitoring program which is the most critical goal. The reason that I chose ten years is that western pond turtles do not reach sexual maturity until about ten to fourteen years of age (Bender 2009). Thus in order to see if the headstarted turtles will start a viable population (one where the intrinsic rate of increase is positive) we must wait and monitor them until sexual maturity to see if they reproduce. The indicator of success of this restoration project would be that a majority of hatchlings survive and reproduce. In the wild under normal circumstances the average hatch success is seventy percent, so for this project we should aim for around this percentile (ECCC 2006). It is also important to be able to tell the headstrated turtles apart from other emigrated turtles quickly. I suggest marking the turtles with paint on the shell or toe clipping so that headstarted turtles can be easily seen so that data can be recorded on survival rates and reproduction. Monitoring the site should also include trapping of red-eared sliders if they reestablish at the site, adding more basking logs if necessary and making sure that the buffer zone surrounding the pond is free of woody forbs.

In order to improve this restoration plan there should be more research on dispersal and translocation. There is no data on survival of adults translocated from other locations for restoration to another site. If this method works than it could help to accomplish the goal of a viable population much faster, however, if it does not then we have lost even more fertile adults. It is also unknown how far these turtles will disperse to know if pond turtles might come from surrounding areas to colonize. Some research suggests that pond turtles have high home range fidelity. This would mean that the headstarted turtles would remain at the site to start a population and would not disperse, and that adults from other sites are unlikely to disperse to this site (Ashton 2009). This restoration project could be very insightful because there is not very much research that has been done on the western pond turtle because of its sensitive status. This project would allow research to be conducted on survival rates, dispersal, and the viability of transplanting adult reproductive pairs.

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Student presentations for ENH 160 given May 5th through May 19th, 2009

Amanda

Beckenhauer

ENH 160

Giant Garter Snake (*Thamnopsis gigas*)

Goal:

To create or recreate a habitat that will support and help reestablish the giant garter species (*Thamnopsis gigas*) sustainably.

Background information:

In 1971 California recognized the giant garter snake as a threatened species. Two decades later, in October of 1993, it was listed as a federally threatened species. The number that was given to the species was 2C which meant it had a high degree of threat but also a high recovery potential. There have only been 13 recorded populations in California; "(1)Basin, (2) Colusa Basin, (3) Sutter Basin, (4) American Basin, (5) Yolo Basin/Willow Slough, (6) Yolo Basin/Liberty Farms, (7) Sacramento Basin, (8) Badger Creek/Willow Creek, (9) Caldoni Marsh, (10) East Stockton – Diverting Canal and Duck Creek, (11) North and South Grasslands, (12) Mendota, and (13) Burrel/Lanare" (Karen J. Miller, 1999).

The first known recording of the giant garter snake was in 1908 in its endemic state of California. The giant garter snakes are native to the Sacramento and San Joaquin valley regions because they include the landforms necessary for the Giant garter snake to survive. Their habitats need to include:

1) Sufficient water during the snake's active season (early spring through mid–fall) to maintain an adequate prey base

2) Emergent vegetation, such as cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.), for escape cover and foraging habitat

3) Upland habitat with grassy banks and openings to waterside vegetation for basking

4) Higher elevation upland areas for cover and refuge from flood waters during the

snake's inactive season. (East Contra Costa County HCP/NCCP, 2006)

The water can be present in many different forms such as waterways or canals, small lakes, oxbow lakes, and ponds. Large, deep waterways are not favorable to the snake because large fish, such as trout, are predators to the giant garter snake. These large water ways also often lack grassy areas along the banks. The Giant garter snake's diet consists of insects and small fish such as carp, mosquito fish, and tadpoles (native species including blackfish- *Orthodox microlepidotu* and the Pacific treefrog- *Hyla regilla*). The best area of water for the giant garter snake is one that is seasonally isolated from a larger waterway. In this situation a few small fish are also isolated, which makes them an easy meal for the snake. Going outward from the water is where the grassy/herbaceous area is present. This is necessary not only as a place to regulate the snake's body temperature and foraging, but also as a place to escape and hide from being preyed upon. The Giant garter snakes range in coloration from a brown to olive to tan, which camouflages it throughout the grasses. The distinguishing characteristics though are three stripes stretching the length of their body and side rows of black dots. Predators include all types of animals and reptiles from birds, to mammals, and even bullfrogs. These include "raccoons (*Procyon lotor*), striped skinks(*Mephitis mephitis*), opossum (*Didelphis virginiana*), red foxes (*Vulpes vulpes*), gray foxes (*Urocyocinereoargenteus*), hawks (*Buteo* spp.), northern harriers(*Circus cyaneus*), great egret (*Ardea alba*), snowy egret

(*Egretta thula*), American bittern (*Botaurus lentiginosus*), and great blue herons (*Ardea herodias*)" (East Contra Costa County HCP/NCCP, 2006). The last area the giant garter snake must have present in it habitat is an upland area. Although the snake likes to hang out in and around the water it is susceptible to drowning. This upland area keeps the snakes out of floods and is also where their burrows are.

Annually, there are two main seasons for the giant garter snake, an active season (approximately March 1 to October 31) and the inactive season. During the active season the snakes mate, eat, swim, and bask in the sun. During its active season the Giant garter snake breeds twice, first between March and May and then briefly again in September. Once emerging from their inactive season the males begin searching for females to mate with. "Females brood young internally and typically give birth to 10 to 46 young (mean = 23) from late July through early September" (East Contra Costa County HCP/NCCP, 2006). At this time the young disperse into dense coverage, absorb their yolk sac, and start feeding independently (occasionally on one another). The male Giant garter snakes reach sexual maturity at around 3 years, while the female takes about 5 years. Although most individual snakes are small in size, the Giant garter snake is considered the largest of the garter snake species because some adults can reach a length of more than 5 feet. During the active season the Giant garter snake finds a mammal burrow or two or riprap which it uses for regulating it's body temperature and hibernation. They typically select burrows with sunny exposures along south and west facing slopes (Karen J. Miller, 1999).The inactive season is when hibernation occurs for the snakes, although they have been known to leave their burrows for a few hours on a sunny day to bask or move. During a Wylie study in 1997 in the Sacramento Valley, 50 percent of the radiotelemetered snakes were observed, at some time, basking or moving short distances in winter (Karen J. Miller, 1999).

There are two main things that have continuously been decreasing the giant garter snake species; humans, and climate change. These two things can be the cause and effect of one another, therefore both are closely related. Climate change directly affects the seasonal amount of water the wetlands are receiving. During hotter seasons the wetlands lose water and dry up, while in the wetter seasons there is an excess of water and the wetlands tend to flood. Unfortunately, in the last century California has been highly urbanized due to rapid population growth. This population boom has causes urban sprawl, which leads to the degradation and demolition of natural habitats of the giant garter snake along with many other species. Land has been rapidly cleared in past decades to build housing, roads, building complexes, and for farming. These human practices have negative effects on the giant garter snakes. The most detrimental effect is that it isolates populations which:

1. Forces them into habitats that don't include the necessities they need to survive such as food, protection, and water

   -Forces them into open and/or riparian habitats leaving the Giant garter snake in an area with too much cover (lessening its ability to thermoregulate body temperature) or no coverage at all for escaping and hiding from prey.

2. Introduces them to new species that are potentially infected with diseases or become predators to the snake
3. Smaller populations with less genetic diversity

To keep up with the growing human demands natural waterways are being disrupted by dams, levees, and canals, channels and are being redirected. Water is being redistributed from its natural routes to underwater pipes to feed into the cities and farmlands. Not only is the absence of water affecting the snakes but also the construction that goes along with creating the new underground waterlines. Some impacts to the native giant garter snakes are:

1. Large heavy vehicles driving over snakes and/or their burrows suffocating the snakes
2. Frightening the snakes away from their habitats, into a coverless area
3. Hansen and Brode in 1993 observed that ongoing maintenance, including scraping canal banks, mowing, and applying herbicides, prevented establishment of vegetation in newly relocated canals within the Natomas Basin (Karen J. Miller, 1999).
4. Levees and dams cutting off or increasing water supplies directly affecting the giant garter snakes water supply, food source, and flooding

Human attempts to clean up and manage wetland has led to the degradation of the giant garter snakes natural habitat by;

1. Attempts to control invasive weeds takes away from the amount of surface coverage the snakes have to get away and hide from prey (Karen J. Miller, 1999)
2. Attempts to control rodents lessens or eliminates the amount of underground burrows the snake needs for retreat (Karen J. Miller, 1999)
3. Lack of flood control, less or no summer water provided, and contaminated drain water being used on wetlands. (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006)

4. Agricultural and flood control activities have extirpated the giant garter snake from the southern one third of its range in former wetlands which were associated with the historic Buena Vista, Tulare, and Kern lakebeds (Karen J. Miller, 1999).
5. In the grasslands, wetland management changes on State Wildlife Areas and private duck clubs affect the availability of summer water which is necessary to provide giant garter snake foraging habitat (Karen J. Miller, 1999).
6. Livestock overgrazing along the edges of water sources degrades habitat quality in a number of ways: (1) eating and trampling aquatic and riparian vegetation needed for cover from predators, (2) changes in plant species composition, (3) trampling snakes and burrows needed for shelter, (4) water pollution, and (5) reducing or eliminating fish and amphibian prey populations. (Karen J. Miller, 1999)

In attempts to learn more about the giant garter snakes, the snakes must be collected and/or tagged. Although the majority of these practices are authorized by permit, they have still been known to have negative effects on such as:

1. The capturing and short term confinement leads to great amounts of stress and fluctuations of blood plasma corticosterone levels. Too much water in a container can be suffocating while not enough can decrease the snake's ability to thermoregulate.
2. Floating minnow traps use mesh to capture reptiles which have been known to be defective, trapping the snakes increases the risk of predation and the longer the snake is in the trap the less it is able to regulate its body temperature
3. While in holding snakes can be submitted to and likely become transmitters of diseases and infections that don't appear in their natural habitats.

Specific manmade sites that have become beneficial to the giant garter snake are rice fields.

> Rice fields contain warm shallow water with sheltering emergent vegetation (i.e. rice plants) which is present within the fields during the giant garter snake active season in the spring, summer, and early fall. During the late summer when rice fields contain large numbers of mosquito fish and Pacific tree frogs, rice fields may provide important nursery areas for newborn giant garter snakes. (Karen J. Miller, 1999)

One thing that isn't beneficial to the giant garter snake species within rice fields is that herbicides and insecticides are occasionally used, effecting the amount of weeds/coverage surrounding the fields and decreasing insects which are food sources. The economy also has an effect on the number of rice fields needed each year.

Since the ruling that the giant garter snake is threatened, there have been many projects created throughout California attempting to regulate land use, and protection for the giant garter snake species.

> -NEPA (The National Environmental Policy Act) "requires projects to be analyzed for potential impacts to the human environment prior to implementation" (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006).Where significant environmental effects are revealed mitigation must be proposed to offset the effects. The problem with this policy is that analysis is only required for federal plans and not for private landowners. Also NEPA doesn't require impacts to be fully mitigated

-CWA (Clean Water Act) "U.S Army Corps of Engineers regulates the discharge of fill material into waters of the U.S including isolated waters, headwaters, and adjacent wetlands." Defines 'wetlands' as areas which having hydric soils, hydrology, and hydrophytic vegetations. (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006)

-CESA (California Endangered Species Act of 1984) The giant garter snake species was listed as threatened in 1971. This listing regulates the capture of the species to only those with a permit for scientific collection and/or research. (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006)

-CEQA (California Environmental Quality Act) Reviews state or local government agency projects for significant environmental impact. If found lead agencies can require mitigation or decide that overriding considerations make mitigation infeasible. The environmental impacts of the project are required to be disclosed. Environmental impact is defined as 'a sustainable or potentially sustainable effect on the environment.' The problem with this act is that the protection of a listed species through CEQA depends on the lead agency involved. (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006)

-Endangered Species Act of 1973 provides federal laws that offer protection for listed threatened species. In 1993 the giant garter snake species was listed as threatened which requires or recommends projects to follow minimization and avoidance measures of:

1. Limiting activities to coincide with the giant garter snakes active season
2. Surveying for giant garter snakes prior to disturbance or construction

3. Restricting canal maintenance practices, such as mowing, to one side of canal per maintance period. (U.S Fish and Wildlife Service Sacrmento Fish and Wildlife Office, 2006)

Although there are many policies and laws regulating the projects a lot of them contain minimal requirements that have not proven to have any positive effects on the species. There are many studies taking place on the giant garter snake species but because of the fact that these thorough studies are fairly recent our knowledge is limited. “Though there is little data specifically addressing the toxicity of selenium, mercury, or metals to reptiles, it is expected that reptiles would have toxicity thresholds similar to those of fish and birds” (Karen J. Miller, 1999). Other factors affecting scientific studies on the species is that there isn’t a way to record all populations and individuals further limiting information. The fact that a good way of studying this species has yet to be discovered without harming the captured individuals the studies that have taken place are likely to not sufficiently represent the natural population.

For funding USGS has been known to contribute funds to projects for scientific monitoring and tracking of Giant Garter snakes. A few other considerations would be U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, the Natural Resource Conservation Service, the California Department of Fish and Game, and the California Department of Water Resources.

Part II: Goals and management plan

My broad goal for the project is:

To create or recreate a habitat that will support and help reestablish the giant garter species (*Thamnopsis gigas*) sustainably.

This goal will not be successful until a few smaller goals are completed.

1. Recreate a the giant garter snake's habitat

-Choose the area which will be used as or converted into a wetland habitat being sure to connect it to the existing waterways will be used

-Make sure there is a an adequate water supply from late February to early November that will be able to support the Giant garter snake's prey (small fish)

+water should be slow flowing

+not so deep as to house larger game fish which are predator of the species

-On the water banks and up into the lowland area there should be a medium to dense herbaceous coverage for the giant garter snake to escape/hide from prey.

+at least a 20-25 feet from bank to upland area of coverage area filled with water loving grasses and maybe forbs

+can include California blackberry or wildgrape

- The herbaceous area should give way into the pre-existing upland area

+ The upland should be housing less dense grassy areas that are ideal for small mammals to burrow in

+ A few patches on land in which full sun will predominate

+This area should also be far enough away from the water so that it is not susceptible to flooding or have higher elevation land close by

- Maybe adding one or two overflow/vernal pools would help with preventing flooding on upland areas

+recommended mix from another restoration plan suggests at least 20-40% native grass seed[fescue (vulpia spp.), Cal. Brome, blue wildrye, and needle grass], 2-10% native forb seeds[rose-lover and alfalfa], 40-68% non-aggressive European annual grasses[wild oats, wheat, an barley] (Programmatic Consultation with the U.S Army Corps of Engineers)

-no aggressive non-native grasses, [ryegrass, cheatgrass, fescue(Festuca spp.), giant reed, medusa-head, or pampas grass] endophyte-infected grasses, or more than one to two riparian trees

Once the water vegetation and water area(s) are in place, they should be allowed to establish before the giant garter snake is introduced into the habitat.

-grasses/forbs should be at least 2 feet high of continuous coverage in the bank area, lowland area

-small fish and amphibian larvae for the snake's diet should be introduced into the water

- partially covered mammal burrows should be present in the upland areas

2. Introduce the giant garter snake species into the habitat

-the amount of snakes introduced depends on the size of the of the area restored

+ there are no studies that have come up with a certain number per acre though

+ the snakes should be taken from the closest natural habitat(s) to the site

-an equal amount of males and females will be introduced at the same time

+females should be 4 years old and males 2

The giant garter snake species can't be introduced until the habitat can provide enough coverage for escape from prey, animal burrows for hibernation and thermoregulation, and an already established prey base. The snakes that will be introduced should be a year or two away from maturity, females 5 years and males 3, so it can be made sure that the species can live on their own before reproducing.

As time goes by the grassy and forb areas will need to be maintained. When this time comes it is necessary that any work is done during the snake's active season, so the giant garter snake can escape into coverage, and having only one side of the bank worked on at a time. Of course the areas should be monitored. As the vegetation is growing the site should be visited and tested at least once a month for the first couple (2-3) of months to make sure the plants are growing well with no invasions from weeds or pests. The waterways should also be monitored this long to make sure the water is being held and whether or not there are fish present. If no fish are present they some should be added. The area should also be observed for burrowing animals (such as voles), if none are present action should be taken to try and add some to the habitat.

Once the area is stable and needing less human help and the giant garter snake species is added the site will need to be monitored a little more closely. For the first 2 months a trained professional should be at the site once a week recording the number of snakes seen (if any have died), if the water is still housing enough prey for the snake, and burrowing activity. This is mainly to be sure the snake is a adapting well. If the species is adapting well to the new habitat the site visits can become increasingly less frequent for the next year, but never less than once a month. Once the snakes are of age to start mating observations should be made once a week again, keeping track of the number young each week and their success.

Criteria for success of the site:

1. Native vegetation, grasses and forbs, are reproducing on their own with no outside help and successfully fighting off exotics.
2. Waterway fish and amphibians are producing a sufficient number of individuals, enough so that there are still enough young left after being preyed upon to produce new generations.
3. Giant garter snakes introduced into the habitat are for the most part staying on site. They are not getting overcome and killed by large amounts of predators. They are reproducing successfully with new generations every year.

Potential Problems

In adding any living thing to a new habitat there are many potential dangers. One problem would be that a large number, more then 1/3 of what was put on the site, of snakes have been killed by predators or seem to have overheated. In this instance what should be done immediately is to add more tall grasses for cover or maybe plant taller grasses. The grassy coverage is the giant garter snake’s only defense against predators.

Research

The majority of the research for the giant garter snakes has only been on habitats where there are already populations present. There are few, if any, researches about the introduction of the species onto a new site. This is the main reason why the snakes need to be closely monitored for the first few months. Because no information was found on how the species should or is going to act little is known whether or not the introduction will be successful.

Part 3: Trade-offs

Our site is so large that there are few disagreements about what should be placed where and why. There are two main habitats that need to be restored on own site, one being riparian and the other wetland. Though both will need to be close to and use the exiting waterway both are significantly different in what is capable of living there. For example my species the giant garter snake and the western pond turtle both need dense grass/forb coverage, with patches for sunlight to come through for basking. These grasses and forbs need full sunlight to grow, which won't be offered in a riparian habitat because there will be many layers of trees and shrubs which shade most of the soil.

The other two animals that will be added to the site are the white-tailed kite and the Swainson's hawk. Although these can become predators to the giant garter snake, these birds mostly like to eat small mammals/rodents and occasionally insects. The small mammals/rodents, such as the vole, make their homes in the ground (burrows). The giant garter snake uses these burrows to escape from the weather during cold days and nights. For nesting these birds mostly use large trees with prey living close by. The problem here is that trees aren't often found in wetlands. To solve this problem the riparian and wetland areas will be close by one another.

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Swainson's Hawk (Buteo Swainsoni)

Restoration Proposal for 67-acre Davis Site

http://www.swainsonshawk.org/Gallery.html

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ENH160-Restoration Ecology

Swainson's Hawk (Buteo Swainsoni)

Restoration plans for the 67 acre habitat west of the University of California-Davis campus, located within the Central Valley will focus on the introduction of woody plants, grass species, and forbs. Site goals include the eradication of invasive species and reintroducing native plants, focusing on introducing new forbs to the plan area. Animals to be evaluated for potential habitation within and around the site area include giant garter snake (*Silybum marianum*), western pond turtle (*Clemmys marmorata*), white-tailed kite (*elanus leucurus*), and Swainson's hawk (*buteo swainsoni*).

For this report, restoration goals will specifically focus on plans that will either continue success of having Swainson's hawk inhabiting the area or reintroduce the species to the site. Currently the site provides a variety of tree species that would provide suitable nesting habitat, including oak and willow, some near riparian habitat. The site provides open space for foraging. Nearby foraging habitat include row crops such as alfalfa and open grasslands. Further study is needed for the specific types of grasses on the site that would provide habitat for small rodent species, a part of the hawk food supply.

Restoring Swainson's hawk as a viable part of the Central Valley is important to the conservation and sustainable production of agricultural land. The decline in this species over the last several decades is a clear indication of the quantity and quality of agricultural land left in the area. Development of housing in the Central Valley is the prime factor in loss of acreage for both habitat and foraging for the Swainson's hawk, but also the decline in prime farm land and riparian habitat. (Stillwater Sciences, 2003)

Management of Swainson's Hawk

Management of the proposed restoration site and other land around the Central Valley play a vital role in the establishment of a healthier California. Over the last decade, due to state and local laws, Swainson's hawk has made some advances in their recovery Bloom, 1980). From small restoration projects to larger areas reserved for Swainson's hawk, each area continues to help the hawk flourish. The project site has adequate nesting sites, as well as foraging habitat for the hawk. In addition, land uses surrounding the proposed restoration project also provide habitat suitable for Swainson's hawk foraging. The open annual grasses and alfalfa fields provide habitat that would house species hunted by Swainson's hawk (Fulks, UC Davis, 2009). Restoring areas of the site with native grasses and forbs would provide increased areas for foraging. Planting bare soils in the area would provide suitable habitat for other species too. The riparian area on site could be further enhanced by tree plantings. Oak trees could be planted on the north side of the site to encourage future nesting of Swainson's hawk. The tree planting would also hide the current Davis dump site and create a wind break for any unwanted smells that may be created by the landfill. The exotic species on site need to be eradicated and replaced with perennial grasses to increase foraging prey and easy access for viewing from above while hunting.

Surrounding land use: include fallow fields located to the north of the dump (assigned to the Primate Center-no plans to farm or build) containing annual grasses, Glide Ranch (privately owned) to the west having rotation crops, to the south (beyond the creek) is rotation crops, and animal sciences and plant sciences has control over the land to the east of the landfill, which include roses, vineyards, and alfalfa. (Fulks, UC Davis, 2009)

Management of proposed restoration projects as above is only a portion of increasing the population in the Central Valley of Swainson's hawk and the increase of prime farmland. The overall plan would need to involve the cooperation of private landowners in combination with local and state laws. Land ownership directly affects the management outcome of Swainson's hawk, by way of determining the fate of land being developed or not. Nearly 95% of nesting can be found on private land, affecting the outcome of these sites if they are converted to other uses (Woodbridge, 1998). State and local laws that aid in the management of special-status species such as the Swainson's hawk are noted below.

CEQA/NEPA Laws: Habitat conservation in Yolo County is controlled through the HCP/NCCP, which help in guidance of the implementation of CEQA and NEPA laws due to development of land that could provide suitable nesting and foraging habitat. Currently Swainson's hawk is listed by the California Department of Fish and Game as threatened. The range of pairs has declined drastically in California. Historical range of Swainson's hawk in California once extended from southern to northern parts of the state. The majority of hawk pairs currently nest in the counties of Yolo, Sacramento, and San Joaquin. (California Department of Pesticide Regulation, 2009)

The HCP/NCCP and other local agencies provide resources to help in the mitigation of acreage lost to development. Funds for development are provided as a mitigation fee, for example, Yolo County has a fee of $5800/per acre, whereas, Sacramento County has a fee of $18,375/per acre. The fees are used to purchase land that is specifically set aside for threatened species such as the Swainson's hawk (Estep, 2008).

In addition, funding for the project could be acquired for the restoration project through local government grants, research funds and private institutions. The City of Davis should be contacted as regards to the necessary process to get the area to be used as a mitigation banking site.

Swainson's Hawk Review

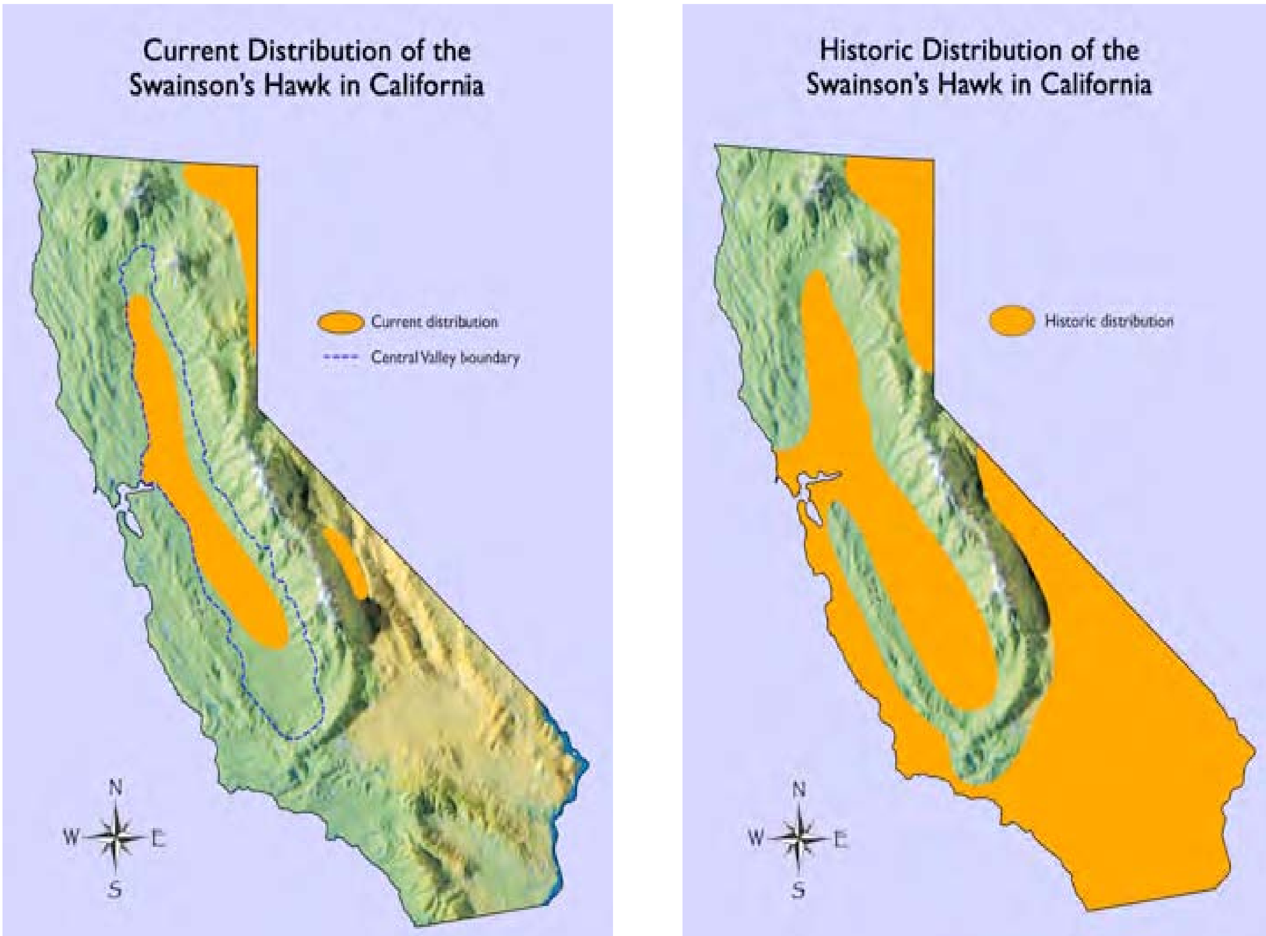
Research for this paper includes a history of Swainson's hawk habitat in the Central Valley, specifically Yolo County with emphasis on population, nesting, biology, migration, foraging areas (including food types and land type), and fledging of the young. The Swainson's hawk habitat varies throughout the State and other territories outside of California. The hawk can be found in areas ranging from southern California to Alaska and through stretches of other parts of the Midwest as far north as Minnesota. The difference of habitat by area would include tree nesting site, prey variety, and water requirements (Nixon, 2007). The habitat specificity in this paper will focus on the Central Valley.

History and Population

Historical records of Swainson hawk populations for pairs in the state of California according to a study done in 1979 were somewhere between "4,284 to 17,136 pairs" (Bloom, 1980). Currently in the State of California, Swainson's hawk pair population is around 2,081 (2005/2006 average) (Richard L. Anderson, Julie L. Dinsdale, and Ronald Schlorff, 2007). The 2005/2006 study by the University of California Davis Wildlife Health Center reported that the estimated Swainson's hawk pairs were 953 for Sacramento, 995 for San Joaquin, and 346 for Yolo Counties (Richard L. Anderson, Julie L. Dinsdale, and Ronald Schlorff, 2007). Historical populations in California are displayed in Figure 1-1. (Estep, 2008) The range has reduced drastically, with only about 90% of original populations. (CDFG, 1993)

Figure 1-1

Historic and current distribution of the Swainson's hawk in California.



(Estep, 2008)

<u>Breeding</u>

Swainson's hawk is monogamous and will mate until one of the mates die. Normal range of lifespan is from 15 to 20 years. Breeding rituals are undocumented in detail, but the hawk is known to do some acrobatics and displays of the wings while in flight (Woodbridge, 1998).

Nesting

Swainson’s hawk nesting generally occurs immediately after the male hawk arrives followed by the female, around mid-March. The construction of the nest is done by the male hawk. Nests are constructed by an array of sticks collected for a nest site, refurbishing old nest sites, occupying old nests of larger raptures, or if nesting is not available, they will build a nest on the ground. Breeding season begins immediately after the arrival of the pair from wintering grounds between the middle of March to the first of April. Nesting sites could depend greatly on the location of foraging habitat and prey availability. (Butte Regional HCP/NCCP, 2008)

Swainson’s hawk nesting generally occurs in tall trees averaging between “15 to 65 feet” (Bloom, 1980). The nests of this hawk correlates with the closeness of riparian ecosystems, usually within a mile of the chosen site. Nesting territory range is usually dependant upon the area and food availability, with both parents heavily defending the nest from predators (Woodbridge, 1998). Breeding pairs in some parts of California could be as close as 60 meters away from each other, where nonbreeding hawks will commune together in foraging areas (Woodbridge, 1998). The hawk can be seen nesting in single trees, small stands of trees or even on tall buildings within urban areas. (California Department of Fish and Game, 1993)

According to a study done in 1979, the most common trees used by Swainson’s hawk for nesting included “cottonwood, oak, sycamore, willow, and other trees that included the pine, mesquite, Joshua tree, and locust”.(Bloom, 1980) It should be noted, that the tree types varied according to location within the state of California. Nesting usually takes place within one mile of foraging habitat, but the Swainson’s hawk will search further for food sources if necessary (Woodbridge, 1998).

Young of Swainson's Hawk

After the arrival and breeding of Swainson's hawk pairs, hatching of eggs occur approximately from April until May. The young are dependent upon their parents for care for up to one month after fledging. (Estep, 2009) After the young leave the nest, the young as well as the adults tend to commune together before the migration south for wintering. Migration south usually begins in the later part of August, even as late as the beginning of fall (Woodbridge, 1998). Migration of Swainson's hawk is the longest of other species similar, averaging nearly 6,000 miles to Argentina for wintering. (CDFG, 1993)

Biology of the Species

Swainson's hawk generally exhibit three colorings of shades ranging from light, rufous, to dark morphs. The underside is light brown or grey with areas of white in the beak and belly area. The hawk averages 18-22 inches in size. Their wings are slimmer than other soaring hawks, which can reach up to 4 feet across. The tips of the wings point upward during flight. Both the female and male species look much the same with the female being slightly larger. Juvenile birds tend to look much the same only darker in areas due to molting. (Woodbridge, 1998)

Foraging Habitat

Landscape best suited to Swainson's hawk pairs is certain types of agricultural fields and annual or perennial grasslands. Agricultural lands suitable for foraging are alfalfa, hay, or wheat, which provide a larger variety of prey. Grasslands best suited to Swainson's hawk are low growing and are not dense, allowing for seeing prey while in flight or perched on high telephone poles or trees. (Bloom, 1980) It should be noted that Swainson's hawk have been known to travel distances up to 10 miles from nesting sites to obtain adequate food for their young. Under normal circumstances the Swainson's hawk nests within a mile of the nest site. (Butte Regional HCP/NCCP, 2008)

Hunting: Swainson's hawk in the Central Valley and other territories are dependent upon open landscape with high quality and a large variety of prey. Crop coverage, if changed from prior years, can greatly affect whether the hawk will continue to inhabit the area. The management of agricultural lands in and around Yolo County determines the outcome of future Swainson's hawk nesting sites. For example, if row crops inhabit prey suitable to the hawk, such as alfalfa fields being converted to orchards or vineyards, prey may become low or non-existent. Swainson's hawk will not forage in dense crops. If crops of this type change from previous years the hawk is not likely to inhabit nearby trees of previous nesting sites and will search elsewhere for food. Farmers who currently manage crops favored by Swainson's hawk can alternate row crops in the area to keep the species actively hunting in the area by planting crops that are best suited to the supply of small prey hunted by the hawk. (Estep, 2009) Swainson's hawk forages for food by flying high to low above open areas of agricultural crops or natural grasslands. (Woodbridge, 1998)

Food/ Diet: In the Central Valley the following wildlife species provide food for the Swainson's hawk including the California vole (*Microtus californicus*) and ring-necked pheasant (*Phasianus colchicus*).(Bloom, 1980) Other food sources may include deer mouse (*Peromyscus maniculatus*), house mouse (*Mus musculus*), western harvest mouse (*Reithrodonotmys megalotis*), pocket gopher (*Thomonmys bottae*), and various birds and insects. (Estep, 2009 and Woodbridge, 1998)

Food Sources:

High Prey Source: Alfalfa fields are considered to be highest value of habitat foraging and prey stock of agricultural fields for the Swainson's hawk. Fields of alfalfa are generally cut monthly and planted every other year, making for a lower coverage to see prey, periodically throughout the Swainson's hawk stay in the Central Valley or the whole season during some years. As alfalfa grows, prey will decrease until the next mowing. Another benefit of alfalfa crops includes flood irrigation, which in turn causes rodent prey to come out in areas of lower cover, causing an increase in prey. Swainsons's hawk has been found to forage in idle fields not being used for row crops. (Estep, 2009)

Varied Prey Source: Tomato crops are harvested in August at the end of Swainson's hawk breeding season and just before traveling south, which was found to be a time supporting a high amount of prey and rodent species, which is generally not the type of prey the hawk is feasting on. Swainson's hawk feasts more on insects, specifically grasshoppers, during the time just before traveling south. (Estep, 2009)

Low Prey Source: Two crops that are similar in growth cultivation, and have a low prey availability are sunflower and safflower plants. Both of these crop covers have a fast growth rate, dense foliage, and are not harvested until the Swainson's hawk is beginning migration for the winter. The hawk is not able to forage in these types of fields due to the top story of canopy cover (Estep, 2009).

Corn fields are similar in Swainson's hawk prey availability to sunflower and safflower crops in that they have low foraging availability during most of the breeding season and harvesting does not occur until late in September. (Estep, 2009)

In addition to the above crops in the Yolo county area, crops with low availability of rodent prey include garlic, bell pepper, orchards, and vineyards. Most of these crops have low prey potential and foraging availability due to high cover and density during most of the Swainson's hawk breeding season and bare ground cover, which does not provide suitable habitat for rodents and food supplies. (Estep, 2009)

<u>Restoration Plan for the site</u>

Current conditions of the proposed restoration site provide suitable on- and off-site nesting habitat for Swainson's hawk. Foraging habitat surrounding the proposed site consist of alfalfa fields, annual grasslands, and various other row crops. The alfalfa fields and annual grasslands surrounding the restoration site provide abundant prey during breeding season through migration in early fall. Restoring annual grasses, forbs, and additional trees to the site would further encourage Swainson's hawk to nest on or near the site. The two existing ponds, nearby Putah Creek, and the manmade water channel (south side of the proposed site) provide riparian habitat that is consistent with the nesting success of Swainson's hawk within the Central Valley.

<u>Methodology</u>

The proposed restoration site is approximately 67 acres and is located west of the University of California-Davis campus. Methods used to evaluate the site include site surveys, soil samplings for nutrients, compaction testing, and vegetation samplings. Information compiled from the site, pictures for documentation, and research of the current and proposed vegetation to be used for the proposed restoration project will be compiled and used by the current management of the site. In addition, species of special concern such as the Swainson's hawk, white-tailed kite, western pond turtle, and giant garter snake will be considered as part of the overall project.

The Swainson's hawk existence does not directly depend on the specific site targeted for restoration, but would benefit by increasing nesting and foraging acreage in the Central Valley. On-site vegetation consists mostly of exotic species and a variety of non-native grasses. Trees on-site, such as the valley oak and willow provide optimal nesting opportunities. Restoration of the site will include the implementation of a variety of grasses, forbs, and trees, as well as the improved conditions to improve habitation for a variety animals, birds, reptiles, amphibians, insects, and pollinators. The issues directly related to this report will look at a main plan targeted toward Swainson's hawk.

<u>Plans/Goals:</u>

Goals-General:

Short term goals for the site include the observation of the site to assess the amount of water during the rainy season collected in several of the basins, use of goats to clear areas overgrown with invasive species, prescribed burning, the introduction of fast growing grasses, and the absence or limited use of herbicides.

Long term goals for the site include the introduction of forbs, native trees, and grasses sensitive to burning and goats. Infill to Basin 1-5 would provide foraging areas that mimic open natural rolling hills and flat areas typical of California landscape. Both annual and perennial grasses could be planted on the hills (an example are the rolling mounds on the east side of the property or the research area south of the site), and the addition of a retention or holding pond for rainy seasons and overflow.

Goals-Specific to Swainson's hawk:

Short term goals for Swainson's hawk include observation for the presence of the bird on or surrounding the proposed restoration site, introduction of annual and perennial grasses to increase vole, squirrel, and mouse populations, prescribed fires prior to breeding season or after migration south to enhance the growth of native grasses and forbs, and goats to mow dense areas on site that will increase foraging areas for the hawk.

Long term goals for the restoration site that would benefit Swainson's hawk include the planting of trees that the species nest (valley oak and willow), monitoring of grasses planted for continued success, planting of forbs to encourage bugs that would provide food later in the season before the hawk's migration south, and implementation of a schedule for use of any herbicide use not to be done before, during, or after migration of Swainson's hawk.

Optional Plans:

Implement Plan A, except for the additional use of goats and prescribed burning during the first five years of monitoring the site (late fall to late winter) done once a year or as needed.

Implement Plan A, except for the addition of a retention pond in either Basin 1 or unnamed basin (drainage overflow from land fill) and the use of herbicides before restoration to control invasive species (i.e., Himalayan blackberries and milk thistle) for the first five years.

Timeline (As funding becomes available): Below is a general guideline for implementing the restoration goals set out for the proposed site.

Year one:

- Monitoring for presence of Swainson's hawk should be done in the first year of planning for restoration of the site;
- If herbicides are used, applications should be done prior to nesting season and after migration for the Swainson's hawk (between October through Early February);
- The use of goats would be an inexpensive and an environmentally safe way to clear areas of weeds and invasive species; and
- The use of prescribed burning, if local air quality authority will allow (done in late fall or early winter) would not only provide re-establishment of native species, but would help keep invasive species under control.

Year Two:

- Start planting annual and perennial grasses on sections that had been cleared in year one;
- Continue monitoring for Swainson's hawk on or near the site by way of species or nest observation;
- During the second year the use of goats and prescribed fire should be used to clear areas as needed on the site;
- Oak trees should be planted during the second year and monitored subsequent years to be sure of establishing strong roots (oak trees are slow to establish, thus they need continued observation);
- Begin to discuss plans of the north site water retention pond;
- Monitor water retention during the rainy season on both Basin 1 and the unknown basin (landfill overflow); and
- Some forbs could be introduced during the second year and observed for establishment during the third year.

Year Three:

- Introduction of additional forbs should be introduced during the third year and follow-up on the second year forbs should be monitored for establishment;
- Monitoring during the third year of the basins for rainfall should determine whether an infill project is feasible for additional wetlands to the site;
- Monitoring of the oak trees planted in the second year of the project should be checked for growth and any additional plantings of other species should be done at this time;
- The replanting of grasses if needed, should be re-done at this time along with any prescribed fire burning; and
- The managers should focus on the existing ponds by planting of additional species, such as rushes and sedges.

Year Four:

- Continued monitoring and management as above; and

- Tree management to include re-planting where needed, check diameter and overall health of trees, and remove any support or steaks not needed.

Year Five:

- Continue monitoring and management as above; and
- Check on tree health, plan for any further restoration of areas that could have failed, monitor for any possibility of invasive species, and monitor the success of all species originally to be re-introduced or encouraged to inhabit the site.

Monitoring Techniques: (Pre- and post restoration)

Pre-restoration monitoring of the project site would create a future site for Swainson's hawk that will not only provide potential habitat, but provide habitat specifically to the needs of species that are prey to Swainson's hawk. The site would need to be monitored or surveyed for habitation within the site area for Swainson's hawk nest prior to and during the restoration of the site (monitoring March-May). Nearby croplands already provide adequate foraging land, therefore, the nesting habitat in trees should be closely watched.

Post-restoration monitoring should be done for the first five years closely and every other year thereafter for re-introduction of trees and vegetation that may need re-planting.

Possible Problems:

If restoration of the site is not successful, the Swainson's hawk would not be adversely affected, but would lose some ground in turning unused land to an area rich as a food source. Even if the site is successful and surrounding land is developed or row crops are turned into orchards or vineyards, the hawk would not benefit from the newly restored site. The site would provide an area for nesting and a minimal amount of foraging area, but the loss of surrounding lands for foraging would possibly create a decline in Swainson's hawk for that specific site. If the site fails to produce the results expected, the data collected could be assessed for future projects and what could have been done differently. The data and restoration plan could be revised and tested again in the same or another area.

Lastly, the use of herbicides needs to be done at times when Swainson's hawk is not present, because of the possible ingestion of or the site visit could cause a disturbance that could result in nest or egg failure (Bloom, 1980).

Research to be addressed further:

- A monitoring program should be set up to verify the need of the extension or creation of wetlands on the site and the benefits Swainson's hawk, giant garter snake, western pond turtle, and other avian species?;
- What is the population if any on or near the site of Swainson's hawk; and
- What are the CO_2 affects on the Swainson's hawk to migrate further north for foraging in 10-15 years?

Possibilities

- Basins 2-5 could be filled in or have partial fill-creating a rolling hill affect (similar to the areas east of the two existing ponds);
- Basin 1 could be filled with water or create a permanent retention pond within the next 3 to 5 years;
- In year 1 and 2 eradication of the Himalayan blackberry and yellow Iris around the two existing ponds;
- The introduction of creeping wild rye should be implemented on the east side of both ponds;
- Meadow barley would be a possible choice for the pond area;
- Introduction of the yellow poppy in the first and second year of restoration;
- The open areas should be planted with Fescue and California Brome;
- It is recommended to keep the walk areas around the basin or a few pathways for human travel;
- Human entrance could be allowed along the walkways during non-breeding season or during the time just before migration (late October to early February); and
- The areas where poison oak persisted, Grindella could replace these areas. (2 or 3rd year after eradication).

The proposed restoration of the 67 acre site is a small section of reclaiming open space specifically for the enhancement of California's diverse ecosystems. The success or failure of the site depends on the optimistic outlook of those involved in the management and restoration of the site. Re-introduction of native species is best suited for the first few years of restoration, with the possible introduction of some exotic species. Re-introduction of various species throughout the property site is part of the big picture toward the restoration of the site, but it should be noted that keeping many of the species already established is crucial to the current ecosystem. The current trees on site should be left as part of the habitat occupied by current and eventually future residents of the area.

The importance of Swainson's hawk to the area is needed to balance an ecosystem that thrives from the diversity of annual and perennial grasslands, shrubs, forbs, trees, and various animal species. Swainson's hawk is a highly versatile and adaptable species, but without riparian habitat, favored agricultural lands and open space, their continued decline is eminent. Even with partial restoration of riparian areas, Swainson's hawk could see an increase in nesting pairs.

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ENH 160 Final Project
06/04/09

The White-Tailed Kite (*Elanus leucurus*)

Introduction

The goal of this restoration project is to provide habitat for the white-tailed kite (*Elanus leucurus*). Kites are important predators of rodent populations, which can become agricultural pests, particularly in forage crops such as alfalfa (Getz 1985). The white-tailed kite suffered a drastic reduction in range and numbers in the early twentieth century, likely due to hunting by humans (Eisenmann 1971). Shooting white tailed kites was banned in 1957, and the population has since rebounded. The white-tailed kite has become fairly common in California, while also increasing its range to the north and south (Eisenmann 1971). However, many North American populations have diminished since the 1980s, likely due to loss of suitable habitat (Dunk 1995). Although this species is not currently threatened (IUCN 2008), the recent declines demonstrate the importance of mitigating habitat loss to maintain healthy populations and continue the conservation of this protected species.

Literature Review

Population Trends and Distribution

Eisenmann (1971) documented the recovery and range expansion of the white-tailed kite. While once abundant in North America, as reported by May (1935), areas with breeding white-tailed kites had been reduced to a stretch in California from the Sacramento Valley to the San Diego area, and a portion of coastal Texas and Mexico. By 1971 the white-tailed kite had not only increased in number in California, it had expanded its range into South and Central America, as well as north into Oregon and Washington (Eisenmann 1971).

Eisenmann (1971) reviewed several aspects of the kite's life history that make it "exceptionally endowed for rapid population growth." First, the white-tailed kite is less territorial than other raptors. In a good year kites can be found clustered together during the breeding season (Eisenmann 1971, Erichsen 1995). In addition, young kites often hunt together (Eisenmann 1971). In fact, findings of a study in grassland habitat in Arcata, California suggested that kites use the presence of other hunting kites as a cue to find areas with high prey density, particularly if the other kite appears to be having success (Skonieczny and Dunk 1997).

Second, kites have a large number of potential offspring in one season. White-tailed kites often produce four to five eggs per clutch, and they can have up to 2 clutches per year (Eisenmann 1971). In years of high prey abundance they tend to have larger clutches and are more likely to rear a second clutch (Dixon et al. 1957).

Third, kites are highly adapted to taking advantage of fluctuating prey numbers; they tend to move to areas where rodent densities are high (Eisenmann 1971, Dunk and Cooper 1994). However, it is not known to what extent kites are migratory or nomadic. Dunk (1995) suggested that kites are nomadic, citing the recent range expansion and the 1984 colonization of San Clemente Island, which was 80km from the nearest mainland population in California (Scott 1994). Stendell (1972) believed the kite to be nomadic in times of low vole densities, but resident when prey is abundant.

Fourth, as compared to other raptor species, white-tailed kites are relatively immune to the effects of pesticides. This is because they specialize on herbivorous rodents. The species which were most affected by DDT were those which fed on mesopredators, which consume insects (Eisenmann 1971).

Finally, the white-tailed kite has a high tolerance for anthropogenically modified agricultural areas (Eisenmann 1971). In particular, irrigation has been beneficial to the white-tailed kite, indirectly through its promotion of rodent populations such as *Microtus californicus* (see discussion below). Construction of the Inter-American Highway facilitated land conversion from forest to pasture in Central America, which created suitable kite habitat and enabled their southward range expansion (Eisenmann 1971).

Although populations have rebounded, based on an analysis of data from Christmas bird counts, Larson (1980) characterized their recovery as “slow exponential growth,” and cautioned that environmental factors such as weather (see below) or limiting trophic or competitive biotic interactions could restrict kite numbers. Indeed, Pruett-Jones et al. (1980) noted that, based again on Christmas bird count numbers, white-tailed kite populations began a downward trend in 1975, which was especially pronounced in California’s central valley. Corresponding with this decline was a drought in California (1976-1978), which likely had a negative impact on prey abundance. A significant negative correlation was found between the number of kites sited in the Christmas bird count and the previous year’s rainfall. Additionally, in drought years, sightings of kites in northerly, more mesic habitats increased, while sightings to the south decreased. It was concluded that white-tailed kites are susceptible to weather patterns that affect rodent populations (Pruett-Jones et al. 1980).

Furthermore, white-tailed kite populations showed decreases throughout the 1980s and 1990s (Dunk 1995). Likely causes of this are loss of habitat due to land urbanization, modern farming practices that fail to provide prey habitat, interspecific competition for nesting sites, extensive drought, and disturbance of nests (Dunk 1995, Erichsen et al. 1996). While the white-tailed kite is listed as a species of least concern on the 2008 International Union for Conservation of Nature and Natural Resources red list (IUCN 2008), these recent declines demonstrate the importance of creating habitat to maintain the species and prevent population crashes such as occurred in the early 1900s.

Trophic Interactions

When hunting, the white-tailed kite hovers in a characteristic manner with its wings upwards in a V-shape and its feet pointing down (Pickwell 1932). This particular behavior makes kites easy to distinguish when they are observed in the air. When striking for prey, kites typically descend feet first, although there have been observations of kites diving headfirst (Thompson 1975, Warner and Rudd 1975).

Many studies have shown that, in California, white-tailed kites feed almost exclusively on small rodents, mainly the California vole (*Microtus californicus)* (e.g. Dixon et al. 1957, Stendell and Myers 1973, Waian 1973, Warner and Rudd 1975, Dunk and Cooper 1994). They have also been documented to specialize on house mice (*Mus musculus*) during times of high abundance (Bond 1942). Sarasola et al. (2007) summarized the diet of the white-tailed kite, stating that while in North America they feed mainly on *M. californicus*, in South America they have a more varied small mammal diet. For example, Scheibler (2004) found that white-tailed kites in Brazil have some flexibility in the size of prey they can use, which could be beneficial in times when preferred prey are scarce.

However, despite this ability to feed on varying sizes of rodents, Sarasola et al. (2007) found that kites in South America preferentially ate tuco-tucos (*Ctenomys sp.*). This implied that kites are specialized to prey on social rodents, which are more dependable in their distribution than other rodent species. Stendell and Myers (1973) found that white-tailed kites in Monterey county, California still preyed predominantly on *M. californicus* in years of low vole abundance, implying that they invested more hunting time per vole, rather than moving to another area where prey populations might be higher.

Stendell and Myers (1973) suggested that kites inflict top down control on vole populations. However, there is debate in the literature on the extent to which predators, including kites, influence cycling populations of *M. californicus*. Krebs (1966) thought that predation likely influences vole density, but isn't the main factor causing population fluctuations, while Pearson (1971) thought the influence of predators to be more profound.

Interactions with other bird species

Dunk (1995) stated that white-tailed kites are usually agonistic towards other raptor species, Great Egrets (*Casmerodius albus*) and Great Blue Herons (*Ardea Herodias*), and typically pursue Northern Harriers and Buteos in their territory. However, Erichsen (1995) found that white-tailed kites tolerated many other bird species in their breeding habitat, including northern harriers (*Circus cyanus*), herons and egrets (*Ardeidae sp.*) and American crows (*Corvus brachyrhynchos*). White-tailed kites are outcompeted for territory by Swainson's hawks (*Buteo swainsoni*) (Erichsen 1994, Erichsen et al. 1996).

Habitat

White-tailed kites can be found in grassland, agricultural, wetland, oak-woodland, and savannah habitats (Dunk 1995). Erichsen (1994) performed a GIS analysis of white-tailed kite habitat choice in the Sacramento Valley, and found that they preferred sites with less disturbed (e.g. untilled or native) vegetation. Kites require trees for nesting. They are not particular about the species identity (Dixon et al. 1957), although Pickwill (1932) found a preference for oak trees. They have been known to nest in both isolated trees and in stands over 100 ha in size (Dunk 1995). Stoner (1932) reported observations of white-tailed kites in California building their nests in mature clumps of mistletoe, which may provide shelter.

Erichsen et al. (1996) further analyzed nest success in relation to habitat near Davis, California, and found that successful nests were in groups of trees (although previous studies showed that they can nest in solitary trees, as discussed above), such as hedgerows or riparian corridors, adjacent to areas of foraging habitat at least 50 m x 30 m in size. In addition, successful nests were within 1.5 km of water and at least 100 m from roads. However, eight of 22 nests monitored had these characteristics and were not successful. In six of these cases, which were all in riparian corridors, this was attributed to outcompetition by Swainson’s hawks (Erichsen et al. 1996).

White-tailed kites are most abundant in areas that can maintain large numbers of *M. californicus*, their primary prey (Hawbecker 1940, 1942, Dixon et al. 1957, Dunk and Cooper 1994). For example, kites were more abundant in Santa Cruz County, California in drier years than in years when vole nesting habitat flooded (Hawbecker 1940). It should be noted however, that drought years can have negative impacts on prey abundance (Pruett-Jones et al. 1980) so the effects of rainfall amount on *M. californicus* and on the white-tailed kite will depend on the site conditions.

In a study done near Davis, California, Warner and Rudd (1975) found that white-tailed kites can adapt to expanding agricultural conditions. Kites tended to be found near riparian areas, and they hunted in both riparian and agricultural land types. During the breeding season kite hunting strike efficiency was significantly higher in agricultural than in riparian areas, although kites hunted more often in riparian areas. This led to overall similar numbers of successful hunts in both habitat types. During the non-breeding season, kites hunted in both riparian and agricultural areas equally and preyed on *M. musculus* and *M. californicus* in equal amounts. The preference for *M. californicus* in the breeding season was attributed to the fact that voles gather in irrigated agricultural fields during dry summer months when kites are breeding, but tend to disperse in winter (Warner and Rudd 1975).

While conversion of forest into open land has facilitated the spread of the white-tailed kite (Eisenmann 1971) and agricultural land is often good habitat for kites (Eisenmann 1971, Warner and Rudd 1975), in some cases agriculture produces habitat unsuitable for rodents, and therefore kites (Hawbecker 1942, Dunk 1995). Hawbecker (1942) found that white-tailed kites were beginning to breed near abandoned orchards. However, the nearby hillsides were typically overgrazed, leading to a deterioration of rodent habitat, so kites were no longer found on these hillsides. Dixon et al. (1957) also stated that orchards provided good habitat for kites because the mulch used increased rodent numbers, while cleared agricultural areas were bad for rodent survival. Thus, agriculture can be either beneficial or detrimental to white-tailed kites.

Removal of invasive annual grasses and restoration of perennial native grasses will augment *M. californicus* populations, and therefore attract white-tailed kites. Cockburn and Lidicker (1983) found that *M. californicus* had higher reproductive output and survival in habitats dominated by *Elymus triticoides* because the perennial grass remained green, providing food, longer into the summer than annual plants.

Goals

Overall goal: Create nesting habitat for the white-tailed kite

The biggest population declines in the 1980s-1990s were in Southern California (Dunk 1995). However, the previous population recovery and range expansion of the white-tailed kite (Eisenmann 1971) demonstrated the species' ability to increase their numbers in a central pocket of habitat and migrate to other suitable areas. Currently, they are relatively common in the Central Valley compared to other parts of their range (Dunk 1995). Therefore, the Central Valley could serve as a source population for other parts of the state, where the white-tailed kite has seen recent decreases of up to 38.7% (Dunk 1995). Since the white-tailed kite is fairly common locally (Dunk 1995), reintroduction should not be necessary, and creation of suitable habitat will likely be sufficient to attract kites. The two requirements for suitable nesting habitat for the white-tailed kite are 1) nesting trees and 2) foraging area.

Restoration Plan

Nesting trees

White-tailed kites will nest in both isolated trees and large stands (Dunk 1995), however in the Central Valley they prefer to nest in riparian areas and hedgerows (Erichsen et al. 1996). Because white-tailed kites are outcompeted by Swainson's hawks for nesting sites in riparian corridors (Erichsen 1994, Erichsen et al. 1996), our restoration project should create a stand of trees where white-tailed kites can successfully nest if they are pushed out of the nearby Putah Creek riparian habitat by Swainson's hawks. More than one stand could be created to attract multiple nesting pairs, as white-tailed kites will nest within a few hundred meters of each other (Dunk 1995). Native onsite woody species, such as willows, that are already present should be maintained to provide immediate nesting habitat; once the oak stands are mature these could be removed, if desired. Stands of trees, as opposed to isolated trees, could also provide roosting habitat for white-tailed kites, which form large communal roosts in the winter (Pickwill 1932).

Foraging Area

The white-tailed kite is a specialist predator that, in California, preys almost exclusively on the California vole (*M. californicus*) (Dixon et al. 1957, Stendell and Myers 1973, Waian 1973, Warner and Rudd 1975, Dunk and Cooper 1994). Therefore, they need access to a foraging area that can support large populations of voles. Since vole populations fluctuate, even over short distances (Krebs 1966, Stendell 1972), more than one foraging area should be provided for in our restoration plan. This will allow for the possibility that when prey density is low in one area, it may be high in another. Creating habitat for *M. californicus* will also provide prey for other predators such as Swainson's hawks (Dunk 1995).

Voles prefer mesic grassland habitats (Getz 1985). Perennial grasses promote vole populations longer into the summer drought season than do annuals (Cockburn and Lidicker 1983). In a study done in the same region as our restoration site, successful white-tailed kite nests were adjacent to a foraging area at least 30 m x 50 m (Erichsen et al. 1996). Therefore our restoration site must include grassland habitat, preferably perennial, of at least this size.

White-tailed kites tend to forage in areas where the vegetation has little to no disturbance (Erichsen 1994). Heavy grazing should be avoided in the foraging area. In one case, demonstrating the sensitivity of foraging quality, removing grazing from a California grassland led to a tenfold increase in the number of wintering white-tailed kites (Dunk 1995). Similarly, fire and extensive pesticide use intended to remove the majority of the vegetation would be detrimental to vole populations. Light grazing is permissible, if it maintains enough grass cover for voles.

Since the goal is to create breeding habitat for the white-tailed kite, it is particularly important to avoid heavy grazing during the breeding time of spring-summer. Nesting begins as early as February and continues through August (Hawbecker 1942, Dunk 1995). If heavy grazing during this period is required to remove exotic plants as called for by other restoration goals, then our plan should incorporate multiple forage areas for kites so that grazing can be staggered by year, leaving at least one foraging area undisturbed. White-tailed kite territory size is highly variable, but can be as big as 88 ha (Dunk 1995). Therefore, any ungrazed grassland at our site of about 50 ha should be within the distance kites will travel to forage.

Management

Monitoring the site for use by white-tailed kites will be important. If nesting pairs are present, the nest success should be noted, and timing and location of nesting should be recorded. Monitoring should begin in March, and if nesting kites are present, should occur at least once monthly during the nesting season, through August. This will allow for observations during nesting, early hatching, fledging, and will catch a possible second nesting cycle (see Hawbecker 1942). It would also be good to have a wider monitoring program throughout the North American range of the white-tailed kite, as there is no literature available on the population trends of the species since the mid-1990s. Research focused on interactions with other bird species and the effect on nesting success, particularly the Swainson's hawk, would be beneficial. In addition, banding birds that nest at the site coupled with long term (over 5 years) monitoring to see if they have nest-site fidelity would be useful, as there is little data on this (Dunk 1995).

There are several risks associated with this restoration plan. First, despite planning for their needs, white-tailed kites may not use the site, so designing the restored area for kites at the cost of fulfilling other goals may be a loss. Another risk is that the unmanaged foraging area might serve as a source of exotic seeds. Leaving a plot of grassland unmanaged for a year may result in a buildup of exotic species, which could then persist at the site and move out to other areas. Finally, while the white-tailed kite loses out in competitive interactions with Swainson's hawks, there may be detrimental effects to the hawks as well. For example, hawks may need to expend more energy defending nesting territory at a cost to their reproductive output. More research should be done on the interactions between these two species.

To summarize, the specific restoration plan is:

1. Plant one or more stands of oak trees that can provide future nesting sites.
2. Maintain native stands of trees, such as willows, already present at the site.
3. Establish at least two perennial native grasslands that are 30 m x 50 m or bigger to provide foraging habitat.

4. Avoid heavy grazing or disturbance in at least one foraging area each year.

5. Monitor white-tailed kite nesting success.

Incorporating Multiple Restoration Goals

The main tradeoff in providing habitat for the white-tailed kite is the need to leave an undisturbed foraging area, as grazing and other forms of management have negative consequences for the white-tailed kite's prey, the California vole. This interferes with goal of exotic vegetation removal, and could slow down the transition to native grasses and forbs. It is unfortunate that the timing of nesting coincides with the timing of grazing to remove exotic annual grasses, in the spring. However, leaving at least one undisturbed foraging site each year for white-tailed kites should allow them to persist at the site. Hopefully this is not too large a concession, as all areas can be managed for exotics at least once every two years. In addition, in the long term, the creation of a perennial grassland will be beneficial to the California vole (Cockburn and Lidicker 1983), and therefore the white-tailed kite.

The goal of creating a riparian zone with oak trees coincides well with the goal of providing nesting habitat for the white-tailed kite. The only drawback is that Swainson's hawks outcompete kites in these areas (Erichsen 1994, Erichsen et al. 1996), so creating a stand of oaks outside the riparian area in addition could allow for both species to use the restoration site. The goal of creating an open, grassy area next to one of the ponds for turtle nesting and giant garter snake habitat is also very beneficial to kites, as voles prefer mesic grasslands (Getz 1985).

Overall, the broad goals for the restoration site are in line with the habitat needs of the white-tailed kite. This project represents an exciting opportunity to meet multiple restoration goals, including provision of habitat for the white-tailed kite.

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Ecosystem services

Increase carbon storage on site

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ENH 160
June 4, 2009

PART 1

A. Background and Justification

In April 13, 2009 universal magazine, Times, releases an article of the 'New Age of Extinction'(TIME April 23, 2009). The extinction, what Time calls the 6th extinction, is not about an asteroid or any earthquakes but was about humans that will cause the crisis, what we call anthropogenic. At the worst case every living organisms will go extinct and come to an era, Eremozoic, which humans are the only species alive.

Further out to Europe, London has been running a Low Emission Zone from February 2009, fining carbon taxes to vehicles that emit large amounts of carbon. In France, the Government has planned to diminish the emission of carbon rate 5 % by 2010 and encourage people to ride trains which emit carbon by far less compared to other transportations such as buses, cars, planes, etc. On August 31, 2006 the California legislature passed a bill establishing the most extensive carbon dioxide (CO2) emission controls yet in the United States. The law requires a 25 percent reduction in state CO2 emissions by 2020, with the first major controls taking effect in 2012. The last but not least, we should not neglect U.S.A which in Aril 21, 2009 Obama, President of U.S.A., declared the new era of energy. Taking a round visit to 4 states he addressed the importance of keeping 'Green' and this will be the starting point of the 'Green revolution.'

Why is global warming such a pending problem? Why is everybody talking about CO_2 sequestration and what makes it so crucial to rise as a global issue? It is because the global warming predicted to come at 21st century is primarily caused by anthropogenic factors such as developed countries emitting tons of carbon dioxide into the air and developing countries cutting down trees. Many scientists predict temperature of the earth to rise far high by 2020 compared to 1000 years accumulated. And scientists also foresee that the sea level will increase up to 0.16 m (Titus and Narayanan, 1996) or 0.5 m (Vaughan and Spouge, 2001). Thinking logically, if global warming keeps up the pace the sea level will rise, the climate regions will rise to the North Pole ,and we won't be able to even predict how the disaster will come out. Predictions of temperature rise over the twenty-first century are necessarily uncertain, both because the sensitivity of the climate system to changing atmospheric greenhouse-gas concentrations, as well as the rate of ocean heat uptake, is poorly quantified and because future influences on climate-of anthropogenic as well as natural origin-are difficult to predict(C.E., Stone, et.al 2002). No one knows for sure whether the increase in temperature is due to the rise in earth's climate change or from anthropogenic factors. But greenhouse effect is surely due to CO_2 and we are certain that the CO_2 can be a factor of the increase in temperature.

B. Literature Review

Main factors that affect CO_2 increase

Since 1751 roughly 321 billion tons of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these emissions have occurred since the mid 1970s. The 2005 global fossil-fuel carbon emission estimate, 7985 million metric tons of carbon, represents an all-time high and a 3.8% increase from 2004. Globally, liquid and solid fuels accounted for 76.7% of the emissions from fossil-fuel burning and cement production in 2005. Combustion of gas fuels (e.g., natural gas) accounted for 18.6% (1484 million metric tons of carbon) of the total emissions from fossil fuels in 2005 and reflects a gradually increasing global utilization of natural gas. Emissions from cement production (315 million metric tons of carbon in 2005) have more than doubled since the mid 1970s and now represent 3.9% of global CO_2 releases from fossil-fuel burning and cement production(Marland, G., T.A. Boden, et.al. 2008).

Results from neglecting carbon sequestration

First, Carbon emission can affect water. Extensive experimental data generally supported a conclusion that rising atmospheric CO_2 directly reduces stomatal conductance and transpiration per unit leaf area. Reduced stomatal conductance in elevated CO_2 is almost always associated with a decrease in water loss via leaf transpiration and an increase in leaf water potential and expansive growth(Yiqi Luo and Harold A.1995 Carbon Dioxide and Environmental Stress 394pp). This was the theory but in coincidence there was an actual proof on Yellow River in northern China, Ganges in India, Niger in West Africa, and the Colorado in the southwestern United States. As world got warmer, water levels actually dropped in major rivers(As World Warms, Water Levels Dropping In Major Rivers. ScienceDaily 22 April 2009). On top of this a dramatic increase in carbon dioxide levels is making the world's ocean more acidic, which may adversely affect the survival of marine life and organisms that depend on them, such as humans. The ocean absorbs large amounts of carbon dioxide — about 22 million tons a day — causing the water's pH to decrease or acidify(Ocean Becoming More Acidic, Potentially Threatening Marine Life. ScienceDaily 23 February 2009).

Second, Carbon Emission can affect land, especially soil and forests. When the trees are cut down the carbon stored inside of the tree gets emitted to the air resulting the same effect as normal carbon emission. So this is the reason why deforestation should be abandoned. While deforestation is responsible for about 20 percent of greenhouse gases, overall, forests currently absorb more carbon than they emit. The trees and soils of the world's forests are capturing and storing more than a quarter of the world's carbon emissions. And critical carbon-regulating service could be lost entirely if the earth heats up 2.5 degrees Celsius (4.5 degrees Fahrenheit) or more relative to pre-industrial levels, which is expected to occur if emissions are not substantially reduced(Damage To Forests From Climate Change Could Cost The Planet Its Major Keeper Of Greenhouse Gases, Study Warns. ScienceDaily 21 April 2009).

Third, Global climate change will not only impact plants and animals but will also affect bacteria, fungi and other microbial populations that perform a myriad of functions important to life on earth. It is not entirely certain what those effects will be, but they could be significant and will probably not be good. As global temperatures rise and glaciers retreat, these microorganisms lose their habitat. They will probably go extinct before we can study them and get a better idea of their contributions(Climate Change Could Impact Vital Functions Of Microbes. ScienceDaily 8 June 2008).

Carbon Sequestration Programs

While we have acts on carbon sequestration in eager around the world there are only a few carbon storage programs that are already being held in consistency and mostly others are washed away from incapability. Available technology captures about 85-95% of the CO_2 processed in a capture plant. A power plant equipped with a CCS(Carbon Capture and Storage) system would need 10-40% more energy than a plant of equivalent output without CCS, of which most is for capture and compression(Bert Metz, Ogunlade Davidson, et.al. 2005 Carbon Dioxide Capture and Storage pp3). Potential technical storage methods are geological storage (in geological formations, such as oil and gas fields, un-minable coal beds and deep saline formations), ocean storage (direct release into the ocean water column or onto the deep seafloor)and industrial fixation of CO2 into inorganic carbonates(Bert Metz, Ogunlade Davidson, et.al. 2005 Carbon Dioxide Capture and Storage pp2). On top of this another program was about planting 31 kinds of trees which have been figured out to be effective in storing carbon in the middle of New York. The ideal combination of greenery can increase carbon sequestration and reduce the emission of volatile organic compounds (VOC), such as isoprene, resulting in better-quality air and a reduction in greenhouse gases(Choosing the Right Trees Can Affect Air Quality. Physorg 6 October 2006).

In contrast, one of the programs which had to be stopped in the stage of research was about the plankton. Plankton was known for a natural carbon absorbing organism and was spotlighted around the scientists. By utilizing iron fertilization researchers expected the plankton to embed in carbon and later on sink to the bottom of the sea resulting carbon storage (Pollard et al. 2009 **Southern Ocean deep-water carbon export enhanced by natural iron fertilization**. *Nature*) Researchers analyzed an area of the Southern ocean known to be naturally rich in iron and their report reveals that the amount of carbon sequestered to the deep ocean for a given input of natural iron falls far short of previous geo-engineering estimates(Iron Fertilization To Capture Carbon Dioxide Dealt A Blow: Plankton Stores Much Less Carbon Dioxide Than Estimated. ScienceDaily 29 January 2009).

Key Gaps in Knowledge

The main problem why we can't solve the carbon sequestration issue is because currently we don't have sufficient information of the earth, ecology, and living organisms. Only more research on this field and experience can make the vague respects more clear.

PART 2

A. Goals

1. Change the Rangeland to store more Carbon.

2. Protect the site from fire so that we won't disclose carbon in the atmosphere.

3. Monitor the amount of Carbon storage before and after the restoration.

Change the Rangeland to store more Carbon

Terrestrial sequestration provides an opportunity for low-cost atmospheric CO_2 reductions and usually offers additional benefits such as habitat and/or water quality improvements. Terrestrial CO_2 sequestration efforts include tree-plantings, no-till farming, wetlands restoration, land management on grasslands and grazing lands, and so on. So if we can change the terrestrial sequestration by planting trees and grasses, considering that both contribute to the carbon storage, it will have an effect on the sequestration rate.

Spatial and Temporal scale: We should plant on all five sites. But whether we will plant a shrub, grass, or a tree depends on the nearby environment. For example, site number 1 which is next to the pond gets flooded often so in this case we should plant wetland species. In site 2 and 3 which is relatively higher than the other sites would most likely adjust to an upland species. And number 5 site which is very woody would have already adjusted to large trees. Then it would be better to plant trees in that place or just leave it the way it is. In case of temporal scale we would like to plant the trees or plants at a right time when the organisms can actually apt to the weather. Forcing the plants at a weather they can't live will consequently bring only the death and high cost.

Protect the site from wildfire

In forests of the western US, fire frequency and severity historically ranged from high-frequency, low-severity fires in ponderosa pine and Sierran mixed-conifer forests(Covington and Morre 1994;McKelvey et al.1996) to low-frequency ,high–severity fires in forests at higher elevations, such as spruce-fir and northern latitude coastal forests(Agee 1993;Schoennagel et al.2004) The frequency with which large and severe wildfires have occurred has increased in recent decades, a pattern attributed to both land-use changes(Covington et al.1994;McKelvey et al.1996) and climate shifts(Westerling et al.2006).Wild fires release massive amounts of CO_2 to the atmosphere(van der Werf et al.2006)

<u>Spatial and Temporal scale:</u> We should be ready for the fire in anyplace anytime. There is no spatial scale. In order to do this, from the beginning, we must select plants or trees that are quite resistant to fire. And the examples are Manzanita, Wild Lilac, Summer Holly, Silk Tassel, Toyon, Walnut, Buckthorn, Sumac, and Oak. And these are the California Native species so it can possibly apply to our own site(Bob Perry 1981).

And in a temporal scale we should thin out the grassland when it gets dry in order to prevent fire. Since the leaves fall off around august to the winter and the most dry period is summer we should thin out at just before summer comes and also at summer.

Monitor the amount of Carbon storage before and after the restoration

We have to know whether our restoration project (carbon storage on site) has paid off. In order to see the difference we should check the amount of carbon storage in the site and compare with the result after the restoration project is held. In this way we will have a better notice on when and where we had a problem so that we can solve the problem in case there has been no change in the amount of carbon storage.

<u>Spatial and Temporal scale:</u> Since we are planning to plant a different organism in different sites we should at least measure 5 points inside each site. And to compare the value from the places where carbon storage is not held it would be better to also measure at the outside of the site. Considering temporal scale we must measure before the restoration and after the restoration. Sampling the SOC and measuring the amount of carbon stored will take a day.

Potential for restoring these goals (trade off, feedbacks, interactions, and thresholds)

When we change the rangeland to store more carbon, at first, it will have more carbon out to the atmosphere caused from mowing and tilling. But later in the future it will have a better consequence than now ending up as a better site for carbon storage. When we think of fire, actually it is a good way to get rid of exotic species. So if we put fire will have to lose some native species and let out carbon to the atmosphere. These would most likely represent the trade off. In monitoring carbon, we would have trouble measuring the exact amount of carbon. The soil near the tree that has a huge root and big biomass will detect a lower amount of carbon compared to a plant with low root to shoot ratio. But we can't take thousands of samples around the site in order to have a mean of the carbon. It'll take too much time and money. These are the problems we should have in mind.

B. Restoration Plan

Methodologies

1. High Root:Shoot biomass

Plants with a high Root:Shoot biomass had a higher rate of carbon storage(Justin D.Derner et al.2005). So when we select a plant it would be better to select plants that has a high Root: Shoot biomass rate. The examples are Aristida longiseta, Bouteloua gracilis, Buchloe dactyloides, Schedonnardus paniculatus, Sporobolus, cryptandrus, Pascopyrum smithii, Stipa comate, Sphaeralcea coccinea, Artemisia frigid, and Ceratoides lanata.

2. Grazing

The grazed site of the shortgrass(below 50cm) community had 24% more whole-ecosystem carbon storage compared to the ungrazed site. And grazing has a significant effect on total root biomass in the midgrass(50 to 100 cm) community(Justin D.Derner et al.2005). So in either way if grazing is held it will be beneficial. The shortgrass will store more carbon and the middle grass becoming greater in the Root:Shoot biomass rate will also(mentioned above) store more carbon.

3. 31 species recommended for storing Carbon. The ones that are CA natives can help.

31 trees were chosen with the best carbon-sequestering ability and lowest emissions of volatile organic compounds and also strong to disease (Eric Ripley and Richard Greene et al.2006).

They are: American basswood, Bitternut hickory, Box elder, Butternut, Chinese juniper, Cockspur hawthorn, Dogwood, Eastern white pine, Eastern red cedar, European hornbeam, Flowering dogwood, Gray birch, Green ash, Hawthorn, Honey locust, Horse chestnut, Kousa dogwood, Littleleaf, linden, Moraine ash, Northern catalpa, Northern white cedar, Red hickory, Red maple, Red mulberry, Red pine, River birch, Silver maple, Southern crabapple, Sugar maple, White ash, and White mulberry.

Of these California Native species are: Box elder, Dog wood, Hawthorn. And the ones in the same Family are: Flowering Dogwood, Ash, Linden, Maple, Pine, and Crabapple. So we should have this in mind and select the species.

4. Ectomycorrhizal plants

Soils with native grasses such as switchgrass have higher levels of a key soil component called glomalin than soils planted to non-native grasses. Glomalin, one of ectomycorrhizal fungi, plant s stored a large percentage of the carbon found in those soils and contributed greatly to soil fertility (USDA/Agricultural Research Service *2008).So we should plant California Native species which have ectomycorrhizal fungi. The examples are oaks, willows, cottonwoods, cunants, Rhamnus species, roses, Cupressus, Juniperus, Saliz, Betula, Corylus, and Acer(* Las Pilitas Nursery 2009).

5. Solution for suppressing wildfire

(1) Thinning: Forests thinned to approach pre-settlement tree density and stand structure harbor substantially more carbon after wildlife than adjacent dense stands that have

not been thinned(Wirth et al.2002). Moreover the biomass removed by thinning is available for wood products or energy generation, the latter replacing fossil-fuel emissions (Pacala et al.2001) Thinning forests for carbon protection also achieves many of the ecological goals of forest restoration(Covington 2000). One of the ancillary benefits of thinning these forests is a reduction in resource competition that increases the growth of the remaining trees(Sheriff 1996). This increase in growth rates could potentially offset part of the predicted decline in the US carbon sink.

(2) Planting un-ignitable plants

Relationships between ignitability and physical and chemical fuel characteristics were used to provide an estimate of ignitability. These rely primarily on total ash, silica-free ash and energy content to determine ignitability. The strategic use of less flammable plants has the potential to be an effective method of fire hazard reduction in parts of the boreal forest where human activity provides both the fuel and ignition agents. Less-flammable plants will not reduce all people-caused fires but could be effective in areas such as right-of-ways, campgrounds or around dwellings, when used(J.C.Hogenbirk and .L.Sarrazin.2005)

Some of the examples that are Native to California would be Manzanita, Wild Lilac, Summer Holly, Silk Tassel, Toyon, Walnut, Buckthorn, Sumac, and Oak(Bob Perry 1981).

Monitoring Techniques

Soil Sampling:

By sampling the soil from the site we will be able to measure the SOC (Soil organic Carbon). By sampling from each site and from 5 other spots from one site we will possibly have an accurate measure of the SOC. And to compare with a control value we should also sample from the outer part of the site. In this way we can keep on track whether the restoration project was useful.

Problems I might encounter and Adjustment Plan

In case the plants cannot adjust to the environment and finally decimate we should first plant only a part of the total seeds we have. It doesn't mean to disperse the least amount but to match the appropriate amount based on scientific research.

If in case grazing is too expensive to purchase we should contact the dairy in UC DAVIS. For the roots to grow to a bigger biomass, it will take time. So to speak, we have to keep the animals for at least three months so that the roots will settle. Using UC DAVIS animals will be an economical way.

Risk and Uncertainties

The research from the literatures were mostly held in a closed condition, laboratory. And one result cannot represent the whole species in the world. For example, shortgrass is too broad. It might only apply to the species the researchers had used. So it may not work in the place where there are many variable conditions.

All the five sites have different soil conditions. Soil condition is one of the most important factors for the plant so it is hard to determine whether the species will grow well on the site to give us the exact rate of CO_2.

The last but not least, the fact that the grazing will store more carbon in the California Native grasses are not known. So in this case we will have to look over time.

What research questions should be answered

- Does the shortgrass apply to all the species that is below 50cm?

  And does the result apply to California Natives?

- Will the CA native species which are in the same family have the same effect as the 31 species mentioned above?

What research questions could be answered

First, when we focus on storing Carbon in the site, it simultaneously has an effect of restoring the site and also preventing wildfire. By grazing not only carbon can be stored, we can also prevent fire. So we can figure out how much we need to thin out or graze in order to prevent fire.

Second, we will be able to find out how much carbon can be stored when the grasses and the trees are in mixture.

Third, whether the grazing in California Native species is effective will be proved.

On top of this, by comparing the plants in different site we can also find out how Nutrients, Soil organic matter, Moisture, Infiltration, and Compaction can affect the plants and whether it will affect the amount of carbon storage.

Part 3

By storing the carbon in the site there will be some tradeoffs. The diversity would be the aspect of the costs. To match the purposes, for example, prevent fire, High root to shoot plants, recommended species for carbon storage, and mycorrhizal plants the species that can be selected will be limited. Second, some of the techniques are not proven in CA native plants. For example the grazing effect may not apply to CA native plants. And high root to shoot rate species may not be able to survive at the site as well. So we will have to take a risk on whether it will be effective.

And also, we are not sure whether some species will adapt to the California environment. These are the tradeoffs we will have to manage. By participating in the prevention of carbon to the atmosphere we will have a better restored site and also a highly diverse species site.

Budget Plan

1. Soil Sampling: Actually can be held in UC DAVIS
2. Grazing by goats: Controversial

1)Approximately 2000$ a month for 300 goats(federal funded)
2)38,000$ divided by 12(months)=3166$ per month

RFQ# 52090017 for Goat Grazing Services
SUMMARY

Description	GOATS R US	GOAT TRIMMERS	GOAT CENTRAL
Annual cost	$ 5,300.00	$ 36,000.00	$ 8,700.00
Transportation	$ 0.00	$ 2,000.00	$ 1,200.00
Miscellaneous			$ 450.00
TOTAL	$ 5,300.00	$ 38,000.00	$ 10,350.00
References	1. East Bay Regional Park Fire Dept. 2. Cal Trans 3. EBMUD	1. Sea-Tac Intl Airport 2. Glimcher SuperMall 3. Renton Municipal Airport	Did not provide
Notes	**CONTRACT AWARDED**		Proposal is deemed nonresponsive because References were not submitted

The following vendor(s) declined: Goat Brushers, Sinclair Family Farm

The following vendor(s) did not respond: Charles Richardson, Brush Busters, Pine Ridge Goats, Eco Systems Concepts, Living Systems Land Management, California Grazing

Cf. 20.85 $ per AUM(Animal per Unit Month) on cow=20.85$*300=6255$ (too expensive and cows emit methane which is much more contributing to the increase of carbon dioxide)

3.Seed price

Name	Price	Name	Price	Name	Price
Summer Holly	*1 packet for* 1*2.8$*	Wild Lilac	*10g $29.44*	Manzanita	*10g 30.72*
Sumac	10g $15.36	Toyon	10g $29.44	Silk Tassel	1 pack $11.52
Oak	250g $80.64	Buckthorn	10g $29.44	Walnut	10g $29.44
Buchloe dactyloides	10g $10.24	Bouteloua gracilis	10g $10.24	Aristida longiseta	?
cryptandrus	10g $10.24	Sporobolus	10g $10.24	Schedonnardus paniculatus	?
Pascopyrum smithii	?	Manzanita	10g $10.24	*Cupressus*	10g $10.24
Sumac	10g $10.24	*Corylus*	10g $10.24	*Roses*	10g $10.24
Buckthorn	10g $10.24	*Betula*	10g $10.24	*Cunants*	?
Stipa comate	?	*Saliz*	?	*Cottonwoods*	100 seeds $16.64
Acer	25g $32	*Juniperus*	25g $29.44	Ceratoides lanata	25g 29.44
Willows	10g $29.44	*Rhamnus species*	10g $29.44	Artemisia frigid	10g $29.44
Sphaeralcea coccinea	10g $29.44				

SUM	240.64	SUM	198.40	SUM	167.68
				TOTAL	606.72

Based on B&T World Seeds http://www.b-and-t-world-seeds.com/sessionCartenh.asp

4.The TOTAL PRICE

Grazing(3166$) + Seed(606.72+?)= **3772.72$ +alpha**

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Fire Management at Putah Creek Reserve

By

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ENH 160, Spring 2009

Dr. Valerie Eviner

Due June 4, 2009

Background and Justification

Fire has long been recognized as a dominant process in grassland ecosystems of California (Biswell 1956). California grasslands historically burned frequently due to both anthropogenic and natural ignition sources, and the conduciveness of the Mediterranean climate (hot dry summers, cool wet winters) to fire (Minnich 1983). Increasing agricultural and urban development after European settlement resulted in implementation of strict fire suppression policies, resulting in a substantial decrease in fire frequency. Currently, most fires in California grasslands are suppressed as rapidly as possible to facilitate the protection of human life and property. Continuing this legacy, one of the broad goals of the restoration effort at the Putah Creek Reserve in Davis, California, is to minimize the occurrence of wildfire in order to protect the adjacent aquaculture facility.

This goal is representative of the fire management dilemma common to many ecosystems in the western United States: how to integrate restoration of essential landscape processes such as fire with the need to protect human life and property. Fire has been used with success in the reduction of exotic annual grasses and the restoration of perennial grassland communities (Menke 1992). However, the effects of fire on species diversity may be highly variable, and subject to local conditions and interactions (Harrison et al. 2003). Furthermore, abundant exotic annuals contribute fine dead fuels which dry out quickly, facilitating rapid rates of fire spread during much of the year which making grass fires easy to ignite and difficult to control. This tendency was manifest at the Putah Creek Reserve in October 2003, when a wildfire burned through the area and threatened the aquaculture facility (Fulks, personal communication, April 6, 2009). While restoration efforts at the Putah Creek Reserve may benefit from the use of fire, it must be carefully applied to ensure achievement of objectives and minimize risk to other values. For these reasons, a sound fire management strategy will be a necessary part of any future restoration plans for the Putah Creek Reserve.

Fire management for the protection of human values (life, property, natural resources) is a difficult goal to achieve in the western United States. While fire exclusion has been recognized as detrimental to many ecosystems, restoring fire to its historic or functional role is confounded by increasing density of human development within and adjacent to wildlands. Fire control is also an increasingly elusive endeavor, as human encroachment into wildlands increases the number of ignitions, and as warming and drying trends due to anthropogenically-driven climate change continue to develop (Brown et al. 2004). In California, eleven of the twenty largest acreage fires, ten of the twenty most destructive fires (by structures destroyed), and six of the twenty most fatal fires have occurred in the last decade (Cal Fire 2008; Cal Fire 2009a; Cal Fire 2009b). Attainment of fire management goals at Putah Creek Reserve will face many of these same challenges.

National, state and local fire management policies include elements that will both facilitate and inhibit the target goal of minimizing wildfire occurrence at Putah Creek Reserve. Fire management at Putah Creek Reserve is primarily governed by California state policy because it is located in the State Responsibility Area (SRA). However, national, state and local fire management policies (i.e. the National Fire Plan, the California Fire Plan, the Yolo Operational Area Standard Multi-Hazard Mitigation Plan) share a common thread in that their priority is to protect human life, property and natural resources from fire (United States Government 2007; Cal Fire 2007; City of Davis 2009). California is uniquely positioned to implement these policies because its fire suppression organization, Cal Fire (formerly California Department of Forestry and Fire Protection, or CDF), is one of the most aggressive and well funded in the world. With numerous fire suppression resources (fire engines, hand crews, bull dozers, helicopters, and air tankers) distributed throughout the state, Cal Fire provides a very rapid response and high initial attack success rate to most ignitions in the SRA. These factors greatly increase the likelihood that any wildfire at Putah Creek Reserve will be rapidly suppressed, facilitating the goal of minimizing wildfires.

However, these same policies also constrain the use of fire to meet restoration goals, despite the fact that fire is a useful tool for minimizing wildfire risk (Minnich 1983). Fire agencies are highly risk-averse regarding prescribed fire, due to increasing liability for damage to human property and life in the event of an escape. Furthermore, there is increasing hesitancy to dedicate fire suppression resources to prescribed burns, especially during fire season, due to ongoing wildfires and potentially delayed responses to other incidents. Finally, prescribed burning is subject to the Clean Air Act and the Health and Safety Code, and it is increasingly difficult to obtain the appropriate permits due to poor air quality conditions (Cal EPA 2008). These policy elements reduce the potential for using fire as a tool for minimizing wildfire risk and achieving restoration objectives.

Potential sources of funding for achieving the goal of minimal wildfire occurrence at Putah Creek Reserve are highly variable, depending on the strategies and tactics implemented. Fire suppression is very well funded in the federal and California state budgets, and can be relied upon regardless of other fire management and restoration activities. Other activities such as prescribed burning and vegetation management will likely need to rely on grants from agencies and non-governmental organizations interested in grassland restoration (i.e. Natural Resources Conservation Service, Audubon Society). Achieving the goal of minimal wildfire occurrence in conjunction with other restoration objectives at Putah Creek Reserve is possible, but will require considerable planning and cooperation between numerous stakeholders.

Literature Review

The challenges facing successful fire management at Putah Creek Reserve depend largely on the other restoration goals. For example, if minimizing wildfire occurrence was the only goal, an easy solution would be to pave the entire area, which would permanently exclude all vegetation, fuel, and fire. However, other ecological and socioeconomic factors are an important part of the restoration efforts and warrant consideration when formulating a fire management plan. These include native and invasive plant communities, wildlife species and their habitat, carbon storage, and land uses such as grazing. What follows is a summary of the pertinent literature regarding fire management in each of these contexts.

As mentioned previously, fire can have highly variable effects on species diversity and the balance of native and invasive plant species. In California annual grasslands, fire can cause a shift in dominance from grasses to forbs (Biswell 1956). Fire can suppress exotic annual grasses if applied in the late spring before they set seed, and promote native perennial bunchgrasses if applied in the summer (Menke 1992). However, altering vegetation types often requires more complicated coordination with other treatments such as planting, grazing, mowing, herbicide and fertilizer treatments. A single fire event can stimulate undesirable woody species by promoting seed germination or sprouting, while two fire events can reduce their abundance by killing seedlings or sprouts (Biswell 1956). Fire effects on species diversity and community composition can vary greatly by site conditions, resulting in increased native species diversity and abundance on serpentine soils, and increased exotic species diversity on non-serpentine soils (Harrison et al. 2003). Using restoration to minimize wildfire (and using fire to facilitate restoration of native plant communities) will thus require intimate knowledge of site conditions, and how the species in question respond to fire and contribute to wildfire risk.

Similarly, fire effects on wildlife species is largely dependent on their ability to escape the fire, their habitat requirements, and how their habitat is affected by fire. The short-term effects on wildlife species are largely dependent on individual injury and mortality, which varies as a function of the species' escape strategy (Smith 2000). Highly mobile species (most above-ground mammals, reptiles and birds) often flee, while less mobile animals burrow to escape the flames. Individual mortality is also greatly influenced by season of burning, with species being most vulnerable during nesting season (Smith 2000). Fire effects on wildlife populations and communities is largely a function of how different species respond to the habitat alterations caused by fire, with fire favoring some species (i.e. late fall or early winter burning improves foraging habitat for Swainson's hawk) and reducing others (i.e. fire reduces hiding cover for the giant garter snake). In grasslands, fire removes most aboveground plant biomass which decreases nesting and hiding cover in the short term, followed by increased plant diversity which can cause a shift in animal community composition toward species adapted to exploit the resources of the post-fire environment (i.e. fresh plant growth for herbivores, improved visibility for predators) (Smith 2000). Recovery of pre-fire grassland ecosystem conditions and animal communities typically occurs within a few years, depending on climatic conditions (Smith 2000). Again, fire effects on wildlife depends on site conditions and the species in question.

Fire management effects on carbon storage depend greatly on temporal scale. Suppressing fire can decrease carbon emissions from burning and increase carbon storage in biomass and soils (Tilman et al. 2000). Modeling simulations (not specific to annual or perennial functional groups) indicate that while annual burning can increase semi-humid grassland plant growth and soil organic carbon in the short-term, nitrogen limitation results in a negative trend in the long-term (Seastedt et al. 1994). Experimentally measured soil carbon flux in sub-humid grassland is greater in burned sites than unburned sites, an effect that is more apparent at a scale of months rather than years (Knapp et al. 1998). It is reasonable to expect that similar processes would occur in Mediterranean climate grasslands of California, although the differing seasonality of precipitation and temperature may affect carbon flux. Minimizing wildfire occurrence appears to maximize grassland carbon storage.

Fire management and grazing interactions are highly complex, with fire affecting forage quality for grazing animals, and grazing animals affecting the fuel available for fire. Fire in grasslands can increase the protein content of grazing animal diets (Hobbs and Spowart 1984). Very frequent burning, however, can decrease the nutrient content of the standing crop (Menke 1992). Grazing can be a very effective tool for reducing fuel loading and fire hazard in Mediterranean rangelands (Perevolotsky and Seligman 1998). Woody fuel load reduction by goat grazing has been measured at 33% for 1-hour fuels (<0.25 inches diameter) and 58% for 10-hour fuels (0.25-1 inches diameter) (Tsiouvaras et al. 1989). This indicates that grazing is useful in eliminating the smaller fuels (1-hour and 10-hour, as opposed to 100-hour and 1000-hour) which tend to carry fire in grass and shrub dominated systems because they equilibrate with atmospheric relative humidity most readily. Usefulness of fire for increasing forage for grazing animals is highly dependent on the timing of burns, and utility of grazing for minimizing wildfires depends on what vegetation the grazing animals consume.

Wildfire occurrence in grass dominated systems depends largely on the amount and type of vegetation present, and the seasonality of atmospheric variables such as temperature, relative humidity, precipitation, and winds. Fire suppression and lack of grazing in grass dominated systems can lead to encroachment by woody plants, which increases the likelihood of intense wildfires (Russell and McBride 2003). This suggests that burning and grazing can help minimize wildfire frequency and intensity by reducing woody and fine fuel loading. Invasion of exotic annual grasses can result in fire occurrence earlier in the spring because the alien species germinate, die and dry out earlier than native species (Brooks et al. 2004). Decreasing the abundance of exotic annual grasses and increasing the abundance of native perennial grasses would delay the drying of fine fuels, thereby reducing fire hazard. California's Mediterranean climate is highly conducive to fires, with cool wet winters providing adequate water for growth of biomass which cures to available fuel during the hot dry summers with frequent high winds (Minnich 1983). However, riparian areas tend to maintain cool moist sheltered microclimates even during the fire season, potentially serving as a buffer to fire spread in which fire frequency, intensity and severity is lower than the surrounding landscape (Pettit and Naiman 2007). While altering climate at the macroscale is infeasible for the purposes of minimizing wildfires, increasing the cover of riparian vegetation may be used as a management tool for blocking fire spread through grasslands.

Goals

- The overall goal is to minimize wildfire occurrence in order to protect the aquaculture facility. This will be accomplished using a combination of fire suppression and fire prevention strategies in an adaptive management framework that facilitates the other restoration project goals. Treatments will vary spatially and temporally, and outcomes will be monitored for the purpose of informing future management decisions.
- Suppress all wildfires (large-scale) as quickly as possible while providing for firefighter and public safety, using minimum impact suppression tactics (i.e. minimizing dozer and chemical retardant use) whenever and wherever appropriate (small-scale). This is both a short-term and a long-term goal because ignition frequency is unlikely to decline over time.
- Utilize prescribed fire whenever possible to reduce fuel loading, reduce invasive species, facilitate native species, and reintroduce an essential grassland ecosystem process. Vary the seasonality, frequency and size of treatments to create spatial and temporal heterogeneity in habitat and fuel characteristics. This is a long-term goal because state and local policies are not currently conducive to small-scale prescribed fire.

- Utilize mowing to reduce fuel height, inhibit invasive species, and facilitate native species. Ensure that treatment timing coincides with the requirements of other project goals (i.e. avoid sensitive seasons for ground-nesting birds). This is a small-scale goal because it is unlikely that the whole area needs to be mowed every year. This is a short-term goal because it will eventually be replaced by prescribed fire, pending conducive changes in policy.
- Utilize grazing to reduce fuel loading, inhibit invasive species, facilitate native species, enhance the local agriculture-based economy, and emulate pre-Euroamerican grazing regimes. Ensure that treatment timing coincides with the requirements of other project goals (i.e. avoid sensitive seasons for ground-nesting birds). This is a small-scale goal because it is unlikely that the whole area will be grazed every year. This is a long-term goal because it has potential to increase economic sustainability.
- Increase native perennial grass species abundance to delay the availability of fuels to burn until later in the summer. Vary the species composition to create spatial and temporal variability in fuel structure and habitat conditions. This is a large-scale short-term goal because self-sustaining native grassland communities should be created after a series of restoration actions across the entire site.
- Increase native riparian vegetation cover to create a buffer to fire spread across the landscape. Align the riparian buffer to protect the aquaculture facility from the likely direction of fire movement (from the north). This is a large-scale short-term goal because a self-sustaining riparian community should be created after a series of restoration actions on a large portion of the site.

Restoration Plan

All wildfires at the Putah Creek Reserve will be suppressed in accordance with state and local policy. The reserve is under the jurisdiction of the UC Davis Fire Department, but it is likely that any wildfire will involve a response from the City of Davis Fire Department and Cal Fire as well. The reserve manager should establish a working relationship with these agencies to advocate the use of minimum impact suppression tactics whenever and wherever possible (i.e. minimize bulldozer and chemical retardant usage), and should be present during wildfire events to act as a resource adviser. If time permits, emergency response vehicles entering and leaving the reserve should go through a weed wash station to prevent the spread of invasive plant species. Burned areas, fire lines and retardant drop sites should be monitored for invasive species establishment and spread, with pre-planned appropriate management actions implemented when they are detected.

Prescribed fire should be utilized as much as possible, because opportunities are rare under current policies. Fuel moisture should be monitored weekly by weighing prepared grass fuel beds and 10-hour fuel sticks during the desired burning season. A remote automated weather station should be set up on site, and data (temperature, humidity, winds) should be monitored daily and compared to spot-weather forecasts from the Northern California Geographic Area Coordination Center in Redding on the day of a planned burn. The strip head fire ignition pattern common in grassland controlled burns should be used on calm days only, while a “backing into the wind” ignition pattern should be used on windy days to minimize the likelihood of escape. Burns should be coordinated with the local Air Quality Management District to reduce airshed impacts, especially by avoiding burning when the central valley is under an inversion layer.

Prescribed fire treatments should vary temporally (spring, summer, fall) and spatially (small and large patch size) to meet the highly varied requirements of native species, and facilitate other goals such as invasive species eradication and carbon sequestration. For example, spring burns are easiest to control due to high fuel moisture, but interfere with the nesting season of many songbird species. Summer burns favor the eradication of invasive plants such as yellow star thistle, but have an increased risk of escape due to high temperatures, low humidities, and gusty winds. Fall burns favor Swainson's hawk, but are often infeasible due to fire crews being sent to southern California. Treatment frequency, seasonality and size should be varied as part of a controlled experiment designed to inform future management decisions. Burned areas should be monitored for invasive species establishment and spread (vegetation sampling transects), native species recovery (vegetation sampling transects), wildlife use (visual assessment), and carbon flux (soil organic matter measurement) every three months (once per season).

Fires are easiest to control when temperatures are low, and atmospheric humidity and fuel moistures are high. In the central valley, this occurs primarily during the winter and spring. However, burning under these conditions may fail to achieve goals such as maximum fuel reduction and invasive species eradication because fire spread may be spatially patchy and fire intensity too low. While burning under warmer drier conditions may be more conducive to these goals, it must be balanced against risk of escape and firefighter availability. Additionally, fire control activities (burning, mowing grazing) designed to reduce fuel loads will be most effective if conducted in late spring, just prior to fire season. Reserve management personnel should obtain training, qualifications and experience in prescribed fire use so a long-term burning program can be developed for Putah Creek Reserve. Part of the long-term goal should be to have sufficient in-house personnel (Type II Burn Boss, Ignition Specialist, Holding Specialist) and equipment (Type 6 fire engine, Mark III pump, 5000 feet 1.5” hose, 5000 feet 1” hose, gated wyes, nozzles) to conduct prescribed fire operations without relying on other agencies.

Mowing and grazing should be conducted at times that are known to reduce invasive species (summer for yellow star thistle) and increase native species abundance (in the fifth year after establishment for creeping wildrye) and minimize impacts to wildlife (in the late fall or early winter for Swainson's hawk). Treatment seasonality, frequency, patch size, intensity, and method (i.e. different animals) should vary as part of controlled experiment to resolve the many uncertainties involved with numerous species’ responses to mowing and grazing. The risk of wildfire ignition by mowing operations should be minimized by mowing only when fuel moisture is high (i.e. during the early morning, after a rain event). In order to prevent soil compaction, mowing should not be conducted when soils are wet. Mowing should be phased out as prescribed fire use increases.

Native perennial grass species should be planted across the landscape, with species composition varied at small spatial scales to create horizontal discontinuity in fuel characteristics. The response of each native perennial grass species to each type of treatment (burning, mowing, grazing), and the response of fire spread to different species configurations should be monitored as part of a controlled experiment to inform future management decisions.

The artificial stream should be moved to flow north of the aquaculture facility to facilitate expansion of riparian vegetation as a buffer to fire spread from the north. The response of each riparian plant species to each type of treatment, and the response of fire spread to riparian fuel conditions should be monitored as part of a controlled experiment to inform future management decisions. Whether riparian vegetation acts as a buffer to or corridor for fire spread is still unanswered, and can be easily addressed here.

Revised Plans and Goals

Because the overall restoration plan encompasses numerous goals for many species with diverse responses to a variety of treatments, there are inherently trade-offs, win-win situations, feedbacks and interactions. With an overall goal of minimizing wildfire, the most obvious trade-off is between species that benefit from fire (Swainson's hawk) and those that don't (giant garter snake). Other trade-offs are between the fire protection benefits of prescribed burning, mowing and grazing and the species that are potentially negatively affected by these treatments (western pond turtle). The major win-win situation is between the fire protection benefits gained by prescribed burning and the eradication of invasive species such as yellow star thistle. Additional win-win situations occur if native perennial grass and riparian plant community cover is increased, which could reduce fire hazard while benefiting the species dependent on these communities. Potential feedbacks could occur, however, if an area treated by prescribed fire area is recolonized primarily annual grass species that are adapted to frequent fire (ripgut brome) and also facilitate frequent fire due to early-drying fuels. Predator/prey interactions between raptors such as the white tailed kite and voles could be altered by grazing and mowing treatments that are designed to reduce fuel loads, but also reduce hiding cover for prey species.

All project goals can be facilitated by varying the frequency, intensity, size, spatial orientation and seasonality of burning, mowing and grazing treatments while still minimizing wildfire potential. With this in mind, the original goals and management plan pertaining to fire hazard reduction requires revision only to the spatial and temporal variability of various treatments. For example, upland areas currently dominated by yellow star thistle should be burned in early summer to reduce fuel loads and eradicate this invasive species. The burned areas should then be seeded with native perennial bunch grasses such as California brome and creeping wildrye to enhance native plant cover, while also encouraging dominance by fuels that don't dry until later in the summer. In contrast, riparian areas should not receive any fuel reduction treatments such as burning, mowing or grazing due to the sensitivity of numerous riparian species (giant garter snake, western pond turtle) to these activities. Instead, riparian habitat area should be increased and strategically positioned to act as a barrier to fire spread, while facilitating the aforementioned species that utilize riparian areas.

The rationale for temporally and spatially variable treatments designed to minimize fire is that they can be tailored to meet the specific needs of each species and goal in the overall restoration plan. The scenarios involving increased wetland and riparian cover along the stream, ponds and basins 1, 3 and 4 would benefit the goal of minimizing wildfire occurrence by providing a barrier to fire spread most of the time. However, these highly productive areas will produce very high fuel loads which could result in a high severity fire if burning conditions should coincide, such as multiple consecutive drought years, high temperatures, low humidities and fuel moistures, high winds, and multiple ignition sources (i.e. a malfunctioning mower throwing sparks). The scenario involving eradication of annual weed species in upland areas such as mustard also facilitate the goal of minimizing wildfire because they reduce the availability of fuels to burn in the early fire season. However, their replacement by native annual forb species could maintain a similar fuel load, reducing any potential benefit in wildfire reduction.

The best scenario for minimizing wildfire is increasing wetland and riparian habitat area because it is likely to act as an effective barrier to fire spread most of the time. In the rare event that burning conditions coincide to facilitate the spread of fire through these areas, there is likely little that can be done to safely suppress the fire anyway. The worst scenario for minimizing wildfire is eradicating non-native annual species and replacing them with native annual species only throughout the entire site, because this will not change fuel conditions. However, this is unlikely to occur because the class consensus seemed to be that spatial and temporal variability in native annual forb cover was most desirable, intermixed with native perennial species. In conclusion, minimizing wildfire will successfully coincide with other restoration goals at the Putah Creek Reserve through the creative design of spatial and temporal treatment variability.

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Tools

<u>Grazing as a Management and Restoration Tool</u>

Sarah Somers

Part I: Project Background and Justification

Since their introduction at the time of European contact, non-native invasive weeds have become an ever-increasing problem in much of the western United States (Stromberg *et al.* 2007). Specifically, in California's valley grasslands, several of these exotics have displaced native grasses and forbs, thus altering wildlife habitat, soil properties, and fire regimes (Stromberg *et al.* 2007, Sugihara 2006).

Perennial bunchgrasses native to California grasslands have different life cycles and growth forms from annual invaders. Perennial grasses tend to grow more slowly, shunting more of their energy into developing extensive and deep root systems that allow them to survive the characteristically long, dry summers of a Mediterranean climate. This supports grazing for livestock and native herbivores alike, for a longer portion of the year as compared to annual grasses. Their extensive root systems help to stabilize the soil and recycle nutrients more deeply and efficiently than annual grasses, whose roots are significantly shallower (Menke 1992).

Conversely, annual grasses germinate with winter rains, grow quickly to produce seed by late spring, and are dead and dried by early summer. Their shorter lifespan allows for minimal root production, and more of the energy is focused on photosynthetic and reproductive shoot formation. When dry, the fine texture of these annual grasses ignite and burn readily, and some species form a thick and continuous thatch along the ground that carry fire quickly and extensively (Sugihara 2006). In addition, mulch or thatch created by alien grasses may inhibit the germination and growth of native plants (Kimball and Schiffman 2003).

To promote the re-establishment of native grasslands and to reduce the probability and severity of wildfires, existing site vegetation must be managed, particularly exotic invasive plants. There are a variety of ways in which to achieve this. Mechanical control by use of mowing, plowing, or discing is one option. However, heavy machinery can cause soil compaction, and rocky or rugged terrain can prohibit its use. Plant biomass is also left on the soil surface after mowing or discing, which increases fuel availability for fire. Chemical control with herbicides has been used in the past, yet there are often concerns associated with water quality, negative impacts on desired species, and high costs. The use of prescribed fires have been a popular restoration tool, but considering air quality, legal restrictions, and the safety of nearby structures, it is not always the most available option.

One of the more feasible restoration tools in some contexts is the use of managed grazing systems. This employs the use of grazing animals, such as cows, sheep, and goats to reduce unwanted vegetation and promote native plants. Its savings in time, labour, machinery, chemicals, and its sustainability are all benefits that need consideration. Grazing has also proven cost effective: Wayne Pearson, weed supervisor in Stillwater County of Montana, estimates that the cost of using sheep to browse weeds costs as little as $0.60/acre, whereas the cost of using herbicide runs about $35/acre (Kott, 2002). Other benefits of grazing animals for weed control are animal products that could be potentially produced at the same time, such as fibers, meat, and dairy. Clearing of brush and grasses also reduces fuel loads, which decrease the likelihood of catastrophic fire.

Literature Review

Grazing to control weeds and promote native plants

The use of grazing systems to manage land for ecological value is very specific to site characteristics and species composition, both desired and invasive. Variations in management can include type of animal used (cattle, sheep, or goats), seasonal timing, duration of grazing, and number of animals per unit area, or "stocking rate". Elements of stocking rate and duration are often lumped together and presented as the "intensity" of a grazing system. Several studies have been conducted to determine the effect all these factors have on plant community composition.

Overall, most studies are in agreement as to which animals are best suited for certain vegetation types. Generally, the diet of cattle primarily consists of grass (~70%), but they will to some degree eat forbs (~15%) and browse nearby shrubs and trees (~15%) (Animut and Goetsch 2008). However, this has much to do with the stocking rate of the herd and the duration of the grazing. De Brujin and Bork found that when cattle were grazed over the course of an entire summer season at low stocking rates, individuals were able to be selective as to what they consumed. Less palatable invasive plants, such as the Canada thistle in this case, were avoided and by the end of the season, had increased in height, density, and were able to produce seed. In contrast, sites that were grazed by a concentrated number of cattle for a shorter duration proved to have the lowest density and smallest individual sizes of Canada thistle (5).

The use of cattle could be cause for concern, however, as their extended presence may negatively impact some soil properties. Murphy and others in 1995 found that soil compaction was notably greater and levels of N, P, K, Ca, and C were lower in paddocks grazed by cattle, as compared to fields grazed by sheep under similar conditions. Soil compaction can reduce aeration and rainfall infiltration, which may hinder future establishment of native plant species. However, Murphy notes that the degree of compaction will vary by soil texture and moisture level. Disruption of the soil surface by deep hoof-prints left by cattle may also facilitate invasion by exotic plants (Popay and Field, 1996).

In terms of diet, sheep are similar to cattle in that they mostly eat grass, though they preferentially eat forbs when available. Sheep will browse shrubs and trees if nothing more palatable is accessible (Animut and Goetch 2008; Peichel and Henry 2006). These preferences work well in the control of weedy forbs and grasses, if sheep grazing is introduced early in the season when annual grasses are just beginning to flower and broad-leaf weeds have just begun to bolt into flower production. This will help to reduce seed set of unwanted species. In an unpublished study reported by Stromberg and others in 2007, intensive mid-spring grazing by sheep was found to reduce medusahead (*Taeniatherum caput-medusae*) by more than 80% the following year. Unfortunately, this timing of grazing coincides with when many native perennials undergo flowering, so 3-4 year rotations in grazing regimes have proven helpful (Menke 1992). Sheep grazed late in fall will also consume thatch left from annual grasses, which releases perennial seedlings from shade in the subsequent season and reduces dangers of mortality from intense fire the following year (Peichel and Henry 2006).

Goats have proven to be the most versatile for weed control, as they will not only eat grasses and forbs, but also shrubs and other species not typically eaten by cattle or sheep. Diet can often by controlled by confining animals to targeted areas with fencing. Goats have been effective in controlling Himalayan blackberry (*Rubus discolor*), poison oak (*Toxicodendron diversilobum*), milk thistle (*Silybum marianum*), and yellow starthistle (*Centaurea solstitialis*) (Holst and Simmonds, 2000; Popay and Field, 1996). About 30% of a goat's diet consists of grasses (Animut and Goetch, 2008), eating all parts of the plant, including the seed heads and stems that cows and sheep tend to neglect. If timed with when seed heads of undesired species first emerge, the seed bank of non-native plants can effectively be diminished. Goats also have an ability unmatched by cattle and sheep to stand on their hind legs to reach lower branches, fruit, and seed pods of nearby trees (McGregor, 2000).

The effectiveness of native grassland restoration by way of grazing is dependent on several factors other than which animals to use. In terms of control or removal of exotic annual grasses, timing is a main factor of concern, whereas duration and frequency is very important for encouraging native grass survival and eventual dominance. One main goal is to time the proper grazing introduction with when exotic plants are most vulnerable. For many grasses, this is at the time of flowering (in the case of using sheep), or as late as initial seed formation, so long as they are not mature (when grazing goats). Timing can be so specific that a delay of a few weeks can tip the competitive balance between native and exotic species. For example, Love (1944) suggested that the increased success of *Nasella pulchra* seedlings following grazing in early April could be attributed to reduced shading by taller annual grasses. However, plots not grazed until later in the same month had higher mortality of young *N. pulchra*, possibly due to the increased focus on the perennial native as annual grasses began to senesce and lose palatability. This, combined with the ending of the rainy season, reduced the chances of recovery by *N. pulchra.*

Timing must be combined with appropriate duration and rest after grazing. If high-intensity grazing is too frequent, carbohydrate production and storage in slower growing perennials will eventually become exhausted, leading to death of the individual. At least 4-6 weeks of spring growth when soil moisture is not limited is necessary between grazing intervals for perennial natives to be successful and dominate the landscape (Menke, 1992). Fields that are consistently grazed throughout the year, especially at lower stocking rates, have been shown to have a higher occurrence of exotic species, lower native species richness, and lower diversity overall (Kimball and Schiffman 2003; Stromberg *et al* 2007).

Grazing for fire management

In addition to outcompeting native plants, non-native invasive weeds—especially annual grasses—are often to blame for increased fire frequency and damage. Their short life cycle is completed by late spring, when temperatures are hottest and fire is likely. They create a continuous thatch of fine fuels, which ignite readily, burn intensely, and carry fire farther distances than it would be carried through native vegetation alone. One of the more characteristic examples is that of cheatgrass (*Bromus tectorum*). This exotic grass essentially forms a contiguous carpet of fuel, connecting shrubs that, in a pristine and un-invaded habitat, are naturally patchy are spatially isolated. Fire would not normally carry in these habitats, but cheatgrass provides fuels that allow flames to spread extensively (Sugihara 2006). In the Sierra Nevada Mountains, neighborhoods bordered by wildlands in Carson City were threatened by wildfire where fuels were primarily cheatgrass and sagebrush. A group of 350 sheep were released into a fenced corridor (200 feet by 3 miles) at the urban-wildland interface. Within a month, fire experts estimated that the speed at which a fire could travel through this grazed area had been reduced by 75%, and potential flame height decreased from 6'-10' feet down to 2'-3'. The money it would have cost to replace one burned home could fund the fuel management by sheep grazing for fifteen years (Chapman and Reid, 2004). In another study, goats were released into a fenced area to browse thickets dominated by scrub oak. Lower branches within the goats' reach were stripped of foliage and the herbaceous layer was significantly reduced to stubble, thus removing ladder fuels by which fire could climb up into the canopy. Shortly after the goats were removed, wildfire swept through the area, burning everything but the grazed portion.

Part II: Goals and Management Plans

Key Goals:

- Reduce wildfire probability, intensity, and spread to the nearby aquaculture center by using grazing animals to decrease fuel loads and create defensible space.

  The grazer of choice will vary across the site, depending on the plant species and life-forms present. In general, goats are best suited for reducing shrubby fuel-loads and lower tree branches (up to 6 feet high) (Lewis 2006), and goats, sheep, and cattle are all effective for removal of fuels consisting mainly of grasses and forbs (Stromberg *et al.* 2007). Initial grazing events will be focused on overall reduction in live fuels, but as much of the dry and woody material will be passed over, other forms of removal will be necessary. Fire is an option for clearing remaining debris if fuel loads are not too extensive and nearby structures are assuredly safe. Where this is not the case, manual or mechanical removal will likely be necessary.

  Follow-up episodes of grazing should be used to maintain lowered wildfire potential, but frequency and timing will depend on which plant species are to be promoted and which are to be targeted for removal.

- Incorporate the use of targeted grazing practices to reduce the prevalence of non-native invasive plants and promote the establishment of native species.

  These practices will be specific to site conditions and restoration goals. Desired plant community type and species will dictate which animal(s) to graze, and the timing and frequency of grazing. In any case, the initial phase of restoration should focus on weed suppression and reduction of invasive weed seed bank, while remaining sensitive to desired plant species, if possible. Peischel and Henry (2006) suggest this phase can last from 2-5 years, and after targeted weeds have been reduced to acceptable levels, less frequent grazing episodes will likely be necessary. Season of grazing can also be alternated to promote native species (Peischel and Henry 2006).

Restoration and Management Plan:

The project should begin with an in-depth site survey to establish detailed vegetation mapping, including species present and relative abundances. This will prove extremely important in determining which grazer(s) to use for removal of undesired species and fuel load. Attention must also be paid to areas where toxic plants occur. For example, milk thistle (*Silybum marianum*) is toxic to cattle and sheep as it causes nitrate poisoning, especially as it reaches wilting. It is not preferred, but is eaten if alternative forage is unavailable. Goats can be used in areas of high infestation, as they will eat the plant in all life stages without harm, and seeds passed through their digestive tract will not germinate (NWCB 2007). Soil moisture content and compaction will also be important. In sites where soils are moist, cattle are most likely to compact and disturb soils, due to their massive size and comparatively smaller hooves.

In general, areas where grasses dominate, grazing sheep or cattle will be most efficient. Grazing should be in early spring, although this may vary based on species composition. This is when grasses are most palatable and nutritious to animals, so reduction in fine fuel loads will be most effective. In the case of exotic annual grasses such as goat grass and medusa head, seedheads are immature, green, and soft. This is the only time sheep or cattle will significantly consume them. Grazing at this time will reduce fuel loads before they dry and are passed over by grazers. In addition, this will reduce seedbanks of several exotic annual grasses that begin to produce seed at this time (Peischel and Henry 2006). Later in the season, seedheads become courser and less palatable. This often leads to preferential selection of greener perennial grasses, such as *Nasella Pulchra* (Dyer 2003). Peischel and Henry 2006 suggest that early spring grazing should not be continued for any longer than 3 weeks before animals (sheep in this case) are moved to a new area. This will allow perennial bunchgrasses time to recover.

Soil conditions may be cause for concern in certain sites, especially when using cattle for grazing. These issues may be most prevalent in Basin 1, which contain almost marshy soil conditions in areas. Extended or repeated grazing by cattle may compact soils. Deep hoof prints could also provide disturbed soils that facilitate invasion. Upland areas will be safer in terms of soil integrity, but cattle often prefer lowlands and areas near water (Stromberg *et al.* 2007), so they may have to be herded or fenced away from these areas.

One point to consider with early spring grazing is the prevalence of broadleaf weeds at the site. In the case of rosette-stage yellow starthistle, consumption of taller grasses reduces shading and subsequently increases the growth rate and size of individuals (Menke 2002). Sheep will eat this plant until spines form, but goats will eat it in all life stages. Integrating a combination of grazing species into grass-dominated sites with yellow starthistle interspersed is recommended.

Areas with extensive shrub and/or broadleaf weed cover are best suited for grazing goats. This is especially applicable to Basin 5, as much of it is infested with Himalayan blackberry (*Rubus discolor*), poison oak (*Toxicodendron diversilobum*), perennial pepperweed (*Lepidium* latifolium) and milk thistle (*Silybum marianum*). The density of these species poses as a fire hazard, and since Basin 5 is closest to the aquaculture center, this basin requires extensive fuels management. Himalayan blackberry is particularly flammable as much of the mounds consist of dead and dried canes. Goats preferentially consume this plant, though only succulent canes and foliage (Popay and Field 1992). Removal of uneaten vegetation will be necessary. Mowing and subsequent herbicide application has been shown to be most effective (Bennett 2007), but goats can be used to remove the root suckers and stem sprouts that will assuredly occur. This is less costly and toxic than chemical control, but must be conducted year round (Anna Van Zuuk, class presentation). Intensity and speed of removal is improved if goats are fenced into large stands of blackberry.

Poison oak is another shrub that is pervasive in Basin 5, but it too is readily browsed by goats (1). Although poison oak is a native, the smoke produced from it during wildfire can cause life-threatening respiratory emergencies when inhaled by firefighters (Anderson 2006). Considering the proximity of the basin to the aquaculture center, quick control of fire is crucial, but the health and safety of those fighting the flames cannot be compromised. Goats could periodically be fenced around stands of poison oak to browse stands and keep densities lowered.

Initial grazing events should be focused on overall reduction of fuels and invasive plant cover. This should be timed in early spring (late March/early April) so that vegetation is most palatable to animals and production of flowering stalks of many invasive species has begun. Intensity should be high, so stocking rates should likewise be high. Animals can be herded or fenced into concentrated groups. Soil disturbance may be a concern in Basin 1 if cattle are to be used, so sheep can be substituted if necessary.

Follow-up grazing events will keep fuels at a minimum, but should also be focused on reducing invasive species and promoting natives. This is achieved by choosing proper timing, grazing animals, and intensities. Again, most events should begin in early spring, but periods of appropriate rest (4-6 weeks) after short intervals of intense grazing (several days until stubble reaches 2 inches) are most effective for promoting native plants. This reduces competition with exotic species for native grasses and forbs.

Late fall and winter grazing may be beneficial when mulch accumulations occur. The reduction in this litter enhances seedling establishment of perennial grasses. Negative impacts on mature stands of bunchgrasses are minimal, provided that sufficient stubble (at least 2 inches) remains to insulate crown from freezing weather (Peischel and Henry 2006).

Part III: Revised plans and goals

For the most part, restoration plans discussed above are little affected by the other goals of the project. One of the largest conflicts with grazing as a restoration tool is the intended promotion of milkweed (*Asclepias fasicularis*). This perennial herb is known to be toxic to sheep and cattle, and can be lethal if more than 1/10 of the animal's body weight is consumed (Caitlin Talkington, class presentation). Fortunately, if surrounding forage is abundant and palatable, animals typically avoid milkweed. Goats can be grazed in areas where milkweed is abundant, as it is not toxic to them. However, goats are not as efficient at grazing grasslands as sheep or cattle, and this is where milkweed plantings perform best. One potential solution is to plant milkweed in large, dense patches as opposed to interspersed with grasses. That way, patches may be avoided, or they could be protected by fencing if necessary.

Appropriate timing of grazing events has some conflicts. Swainson's hawks nest during this time (March/April), and birds nesting on the ground may be affected by grazers. Avoidance of known nesting sites is one possible solution, though it may be difficult to determine these sites. Improvements or increases in above-ground nesting sites are a more likely solution. Fall and winter grazing to reduce mulch accumulation also coincides with timing of the inactive period of giant garter snake, and should be avoided in these areas. However, habitat of the snake is close to the ponds' edges among emergent vegetation, and grazing of these areas is unnecessary and unlikely.

Restoration plans that were decided by the class do not significantly impact the use of grazing as a restoration tool. Goals pertaining to areas around the existing ponds have little effect on grazing, as animals are best kept away from those areas in the first place. There is little that can be controlled or improved by grazing in these sites. For example, yellowflag iris is toxic to all grazing animals, and they are typically avoided. Cattle tend to gather near the edges of water, but this could severely disrupt soils and habitat for Western pond turtles and giant garter snake. As long as they are provided a source of drinking water, there is no reason for animals to be allowed along the ponds' edges.

As grazing is of little benefit in the control of *Brassica* species that are prevalent in the uplands areas, solarization of infested sites was recommended by the class. This should be timed when animals will not be nearby, so that their hooves do not pierce the plastic sheets being used.

Proposed expansion of the riparian areas along the effluent stream is both hindered and supported by the use of grazing practices. Goats can be used to control any large stands of Himalayan blackberry. However, they must be securely confined to stands as they could otherwise decimate riparian trees and shrubs. Willow leaves and young branches, for example, are a favorite browse for goats. Since the larger goal regarding this area is to expand sandbar willow stands, the use of grazing goats must be conducted carefully or not at all. Small infestations of Himalayan blackberry are probably best controlled chemically and/or manually at first sighting. Goat exclosures around willow groves may be necessary.

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Appendix- assighment outline

Spring 2009- Project for ENH 160

Project Scope

The focal experience of this class will be to develop a restoration handbook for the campus' restoration program (part of Putah Creek Reserve). The campus restoration program is charged with multiple goals: some are related to mitigation (and the campus is legally bound to achieve these), others are key management issues (e.g. fire control near buildings), and other goals are not required, but highly desirable (e.g. diversity, ecosystem services, recreational opportunities, etc.). In order to manage for multiple goals, it is critical to bring together the latest information on various components, 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). Each student will make a short presentation to the whole class, so that everyone is familiar with the broad scope of the overall project. As a class, we will then discuss management options that encompass as many of these goals as possible, and you will amend your management plan to encompass a broader array of goals. All individual projects, as well as a class synthesis (taken on by the students in the lab), will be compiled and sent to the campus restoration team, and be made available on the web for other managers.

General approach

The project will be divided into different stages, which will allow you to develop the project step-by-step, and get feedback from your teachers and peers before the final compilation is due. You will essentially be graded twice for each written section you turn in. 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 based on the effort you've demonstrated in addressing the key issues outlined for that part. At the end of the quarter, you will submit a final version of all sections, where you have incorporated feedback from your teachers and peers. The grade of the final version will be based on overall quality and how well you address suggestions you received on your draft 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 project. 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 part (for most sources, that includes author, date of publication, article/chapter title, journal/book title, publisher, city of publication, page numbers). (See the handout attached to the syllabus on avoiding plagiarism for more details on proper citations).

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. 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.

<u>Part I: Project background and justification, literature review</u> Due 4/23
A. Background & Justification: View this as a brief proposal for funding of the restoration target.

- State your broad goal (detailed goals will be addressed in part II)
- 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 on campus, but overall). For example, to what extent are populations in decline?
- What is the history of degradation of your goal?
- What are the local to national laws/policies that constrain or provide opportunities for your target goal?
- What are some potential sources of funding for restoration of this goal?

B. Literature review
A 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.

- What are the main factors affecting your goal (both ecologically and major challenges to restoration)? (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.)
- In particular, 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

Part I should be approximately 6 double-spaced pages, and key information can be summarized in a bulleted form, if desired.

Part II: Goals and management plans- focused on your target **Due 5/21** (At this time, turn in one copy of Part II for grading, and THREE copies of Parts I & II for peer review—part I should be revised based on earlier comments!)

A. Goals: Outline the key goal(s) relevant for the restoration of your focal target (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), be sure to justify your choices. If possible, discuss a few different restoration options (which will really help fit your project into the broad, 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), justify the measurements you have selected as indicators (For example, with complete failure of reestablishment of a population…….. versus establishment at only small, sporadic locations).
- 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 double-spaced pages.

Extra credit opportunity *(up to 10 points)*

Do a restoration budget for your goals, including factors such as: site preparation, labor hours, materials, monitoring costs, etc. (** Note: this can be handed in up to the last day of class).

Class presentation **You will be assigned a date to present- see class schedule**

Briefly present the key facets of your project to the class. Presentations should be 6-8 minutes in duration (no longer!! To fit everyone in, I will need to cut you off if you go over), and 1-2 minutes will be allowed for questions. The point of this is for all classmates to be aware of the importance, constraints, and opportunities of your project, so that we can fit all of these goals together in a comprehensive management plan. Be sure to keep that in mind during your presentations. Remember, we're all part of the same broad restoration team, so we'd all like to see all of these things happen. We'll address tradeoffs and hard decisions in the group discussion following the talks.

This talk should not be a reiteration of everything you've written & researched. Instead, briefly hit on the highlights (think about the brevity and clarity you'd like from your classmates' presentations). Be sure to cover:

- justification for your target goal
- key constraints/opportunities (Be sure to think about this broadly—e.g. if you're working on frogs, will your project be decimated by snakes, grazing, a certain % change in water availability, etc.)
- "proven" restoration techniques vs. uncertainties
- your restoration plan(s) and alternative options- paying particular attention to what management needs to occur, and over what spatial and temporal scales

Peer assessment **You will get the assignments on 5/26, and your reviews are due on 5/28**

You will be divided into groups of 3-4 students. On 5/26 you will receive the full draft (parts I&II) of each member of your group. Read and give both written and oral feedback on each project in your group. The goal of this is to provide *constructive* criticism, helpful hints, and to point out potential tools or problems that the writer may have missed. Your comments should be written- you will need 2 copies; you will turn in the first to the professor (these will be graded), and give the other copy to the project author. On 5/28, your group will spend the class discussing each other's projects and exploring ways to overcome any remaining hurdles in the projects.

Detailed guidelines on peer review are provided in an attached handout.
Peer reviews should be 1 page per project, and should include:

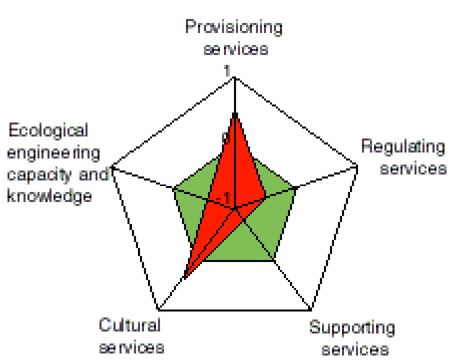
- what the author did well
- general suggestions for what the author might have missed
- constructive criticism

For discussion (15 minutes per project):

- discuss suggestions you made as a reviewer
- as an author, bring up questions you'd like the groups help on
- 15 minute summary- comparison of projects' challenges, unknowns, tools, what you've learned from eachother's projects

Part III- Revised plan and goals **Due 6/4, along with final versions of Parts I & II**

Based on your classmates' presentations and the group discussion of options for managing for multiple goals, discuss how your goals and restoration practices fit in with other key goals. Are there key tradeoffs and/or win-win situations? What are the potential feedbacks and interactions in managing for these multiple goals? How will you revise your original goals and management plan to



accommodate these multiple goals? Compare at least 2 different scenarios using a tradeoff diagram (example on the left)—for example, contrast your original plan's impact on a number of different goals, to your revised plan. What is your rationale for your final choice of goals and management plans (in terms of this new multiple-goal perspective)?

In addition, for *each* of the broad multiple goal scenarios decided upon in the group discussion, write a 2-3 sentence summary of the positive and negative impacts of that scenario on your target restoration goal. Of the group scenarios, which is the best-case scenario for your target goal and why? Which is the worst-case scenario and why?

Part III should be 1-2 double-spaced pages

Final version - BOTH A PAPER COPY AND AN ELECTRONIC COPY IS DUE (electronic copy can be emailed to Dr. Eviner) Due 6/4

The final version should include Parts I-III, merged as one document, and all citations should be grouped together at the end (both in paper and electronic form). Sections I&II should incorporate the comments you received from the teachers and your peers. If you do not agree with some of the suggestions (we're not talking about grammar, but suggestions for shifts in management plans, etc.), you do not have to address every point. However, if there is a substantial conflict between some feedback and your project, you should note that in the final version and justify your reasons for not adjusting the project in response to reviewer comments.