# Proceedings

## California Invasive Plant Council Symposium 2008

Cal-IPC

*"The Future of Invasive Plant Management"*

# Proceedings

## California Invasive Plant Council Symposium
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*"The Future of Invasive Plant Management"*

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Cover: Sutter Buttes – Field trips visited Peace Valley in the Sutter Buttes (pictured), Lassen Volcanic National Park, Big Chico Creek Ecological Reserve, and local creek restoration projects around Chico. Photo: Sara Sweetto: Sara Sweet

Title page: The California Department of Food and Agriculture's Integrated Pest Control Branch won the 2008 award for Organization of the Year. Photo: Gina Darin.

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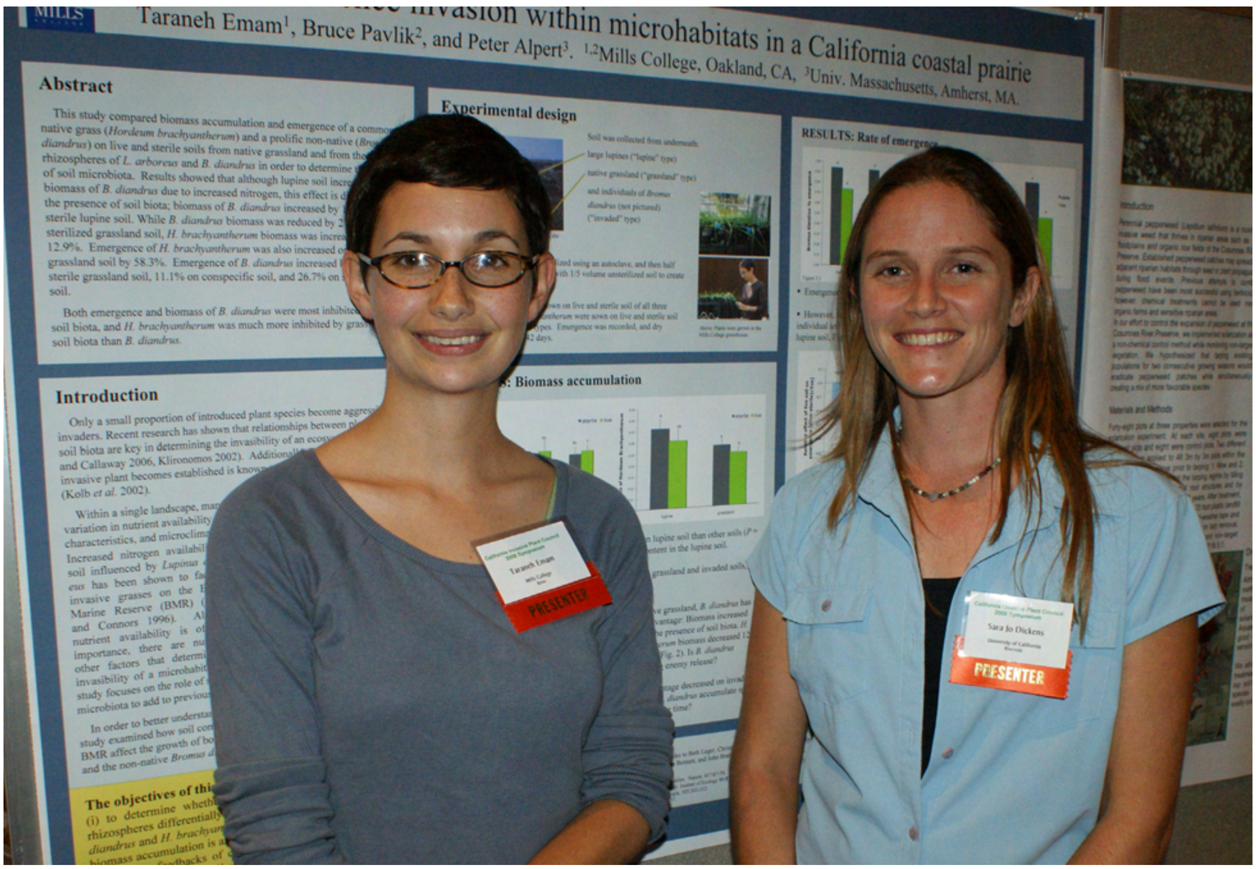
* Indicates presenting author in multi-author papers.

# Foreword

We returned to Chico State University for our 17th Annual Symposium. This year we turned our attention to the future of invasive plant management in many different ways. Theme sessions addressed issues such as climate change, what to do about invasive species we cannot control, and how to develop priorities for guiding research. Our keynote speaker, Dr. Emilyn Sheffield of CSU Chico, described the sociological changes underway in California and how those might affect our work. Finally, we looked at how to help the weed workers of the future. Students met in the first formal Student Chapter meeting and presented their research in the first Student Paper and Poster Contest, while a career panel described the professional options available in invasive plant management and habitat restoration. The Proceedings represent the wide range of invasive plant work underway in California, from research on the effects of nitrogen levels, to field trials of new tools. As always, they address ways to protect California's native habitats through research, restoration, and education.



Taraneh Emam (right) and Sara Jo Dickens received the awards for Best Student Poster and Best Student Paper, respectively. Photo: Bob Case.

# Keynote Speaker

## The Evolving People and Landscapes of California

*Emilyn Sheffield, California State University, Chico. esheffield@csuchico.edu*

California is projected to pass the 50 million milestone before 2040 and add 21 million to its population between 2000 and 2050. From local parks to national icons, California's rich public land heritage forms the backdrop for thriving communities and future prosperity. Consider three key demographic drivers that are changing the face of California and three lifestyle trends that are transforming the timeless relationship between people and nature. Learn how to connect to an increasingly diverse and urban California and in turn build broader relevance for our stewardship and landscape management efforts. Start planning for tomorrow today and embrace the immense opportunity to use your unique professional strengths to connect people to nature and enrich, engage and inspire Californians now and into the future.

# New Horizons

## Learning to Live with Invasive Plants We Cannot Control

*John M. Randall, The Nature Conservancy, Global Invasive Species Team and Plant Sciences Department, University of California, Davis, jrandall@tnc.org*

The goal of biodiversity conservation is to protect viable native species populations and communities and the biological, abiotic and ecosystem processes on which they depend. This requires preventing, minimizing or mitigating threats, including those posed by invasive plants and other invasive species. Unfortunately, in some cases there is no practical or affordable way to control certain invasive plants across areas large enough support and protect the native species and communities they harm. In such situations we need to find other ways to promote the survival and long-term viability of the native species and communities and the processes they need. Four different, but overlapping, approaches to this problem can be identified:

1) Provide native species with refugia from invasive species or their harmful effects, such as competition, vectoring disease, promoting increased wildfire frequency and intensity

2) Manage/restore ecosystem processes that favor natives (e.g. fire, hydrology)

3) Identify individuals/populations of native species with increased abilities to compete with or persist alongside the invasive species and use propagules from them in restoration efforts

4) Change the conservation goal from restoration of a pre-existing community to the 'rehabilitation' of a portion of that community, consisting of the sub-set of native species that can survive under the conditions imposed by the invasive species, or in the most difficult cases to a goal of maintaining or creating a 'new' mixed community that supports key native species along with non-natives and has desirable ecosystem functions and properties

All four of these approaches have been implemented and are underway in a variety of protected areas and other lands valuable for conservation scattered around the world. This is an attempt to provide a comprehensive and systematic overview of how biodiversity can be protected and promoted in situations where one or more harmful invasive plant species cannot be controlled.

## Warmer and Weedier? Outlook for Invasive Plants in a Changing World

*Jeffrey S. Dukes, Departments of Forestry and Natural Resources and Biological Sciences, Purdue University, jsdukes@purdue.edu*

Biological invasions and climate change pose two of our greatest environmental challenges. Individually, each of these challenges has received increasing attention. However, few studies of invasions have considered climate change, and *vice versa*. Such research is important, because biological invasions could drastically alter the responses of communities to a changing climate and climate change is likely to lead to changes in both the movement of species around the planet and the susceptibility of natural ecosystems to invasion.

In general, climate change might be expected to increase the success of invasive species, for a variety of reasons. For instance, a rapidly changing climate should favor species that can extend their ranges quickly and that can tolerate a wide range of climatic conditions. Both of these traits are shared by many invasive plant species. Climate change will also reduce evolutionary advantages that native species have accrued as they adapted to their region's climate.

Few studies have directly addressed the general mechanisms through which climate change could benefit invasive species. However, several studies have characterized responses of invasive plants in a specific area to year-to-year differences in environmental conditions, or to individual environmental changes. My own research in California suggests that *Centaurea solstitialis* (yellow starthistle) can respond strongly to increases in atmospheric carbon dioxide concentrations and so may become more problematic in a future atmosphere.

Climate change will bring new challenges to those managing invasive species, and will increase the need for regular environmental monitoring and coordination among land managers.

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# The Five Stages of Grief: Invasive Plants and the Horticulture Industry

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## Abstract

While the majority of introduced plants are beneficial and serve their intended purpose, a small number move from cultivation into wildlands. Most invasive plants are introduced for horticultural use. Those who introduce and use these plants are often surprised to hear of their invasiveness and those who have not witnessed the invasions often do not understand or believe it. There is a grieving process, much like that following other losses. There is the denial of the problem, often followed by anger towards those bearing the information. There may be a bargaining for limited use of the plant or its cultivars. If scientists and land managers are willing to work with and listen to them, horticulturists may come to accept that a small number of cultivated plants should be avoided.

## Introduction

It is now commonly recognized that invasive plants may have severe impacts in natural areas. In many cases, invaders were introduced for useful purposes and moved from the intentional plantings into natural areas (Reichard and White 2001). Horticultural use accounts for 82% of woody invasive plants in the United States and about 63% of all invasive plants. Individuals, botanic gardens, government agencies, or nurseries may introduce plants for horticultural use. Most of these plants are useful additions.

Those concerned with the management and protection of these areas sometimes have blamed those who sell invasive plants. At times, this has not been done diplomatically. While some may not care about the environment, most nursery owners are deeply concerned. Because they are often working hard to make their nurseries profitable, they may not venture into natural areas and are not fully aware that some plants they sell are invasive. Even if they are told, if they have not seen them invading, they may not understand the magnitude of the problem. Nursery owners (business people often working on a narrow profit margin with perishable products) have felt hurt and then angry that their attempts to provide useful plants to the public were being interpreted as hostile environmental acts.

I have noticed a pattern of response that follows the typical pattern of grieving. In 1969, Elisabeth Kübler-Ross published the book "On Death and Dying," in which she describes the five stages most people go through when grieving, although some people may skip some steps. The first stage is denial. Nursery owners, when first informed that plants they sell are invasive often respond with statements like "it never seeds in my garden or nursery" or "but I can barely get it to grow." They argue about the invasiveness. The second stage is anger, and many have become antagonistic towards those informing them of the invasiveness. The third stage is bargaining, one that we currently see happening around the world, with horticulturists trying to assert that cultivars of invasive species are not invasive and are thus safe to grow. The invasiveness of cultivars is a topic of much current work and is unresolved. In some cases, it may be possible to develop non-invasive cultivars. The final stages of grief are depression and acceptance. Several nursery owners have moved to this final stage and are taking leadership roles in dealing with the issue.

The point of relating invasive species, horticulturists, to stages of grieving is not to trivialize their concerns, but to validate them. Those working in natural area protection should be aware that accepting that invasive species are a problem is a process that may take some time before acceptance is reached. They should assist them with the process and be helpful as they work through their feelings.

In 2001, the Missouri Botanical Garden held a workshop to develop "Voluntary Codes of Conduct" that could help horticulturists from botanic gardens, nurseries, landscape design and other enterprises, chart a path to reducing invasive plants. The Codes are available at www.centerforplantconservation.org/invasives/codesN.html. These codes have provided a convenient way for these groups to address invasive plants and to facilitate interaction among horticulturists and conservationists. Implementation happened slowly, however (Reichard 2004). It became apparent that coordinated efforts were needed. I detail two such efforts in the case studies below.

### Case Study 1: California Horticultural Invasives Prevention (Cal-HIP) and PlantRight

In 2004 a San Francisco-based non-profit, Sustainable Conservation, started a project to connect horticulture and ecologists. They invited people from garden centers, landscape designers and architects, botanic gardens and trade organization representatives from the nursery, floral, seed and other organizations to join their steering committee. Representatives from universities and non-governmental organizations such as the Nature Conservancy and the California Invasive Plant Council also joined. Initial meetings revealed some mistrust. By working slowly, building consensus, however, trust was gained. Regular field trips helped everyone understand the different viewpoints. A trip to natural areas showed the horticulturists the magnitude of the problem and revealed invasions of commonly sold plants. A trip to a large wholesale nursery demonstrated that these are businesses with substantial investments in some species. Predictability is critical to the success of the business.

The projects chosen also developed slowly and by consensus. The first task was to determine what key species in horticultural use invade in defined regions in California, a central theme of the Codes. After careful deliberation, the target species were selected and suitable, safe alternatives recommended. The multimedia PlantRight campaign was rolled out earlier this year with launch parties in three locations. Attention has now turned to developing a risk assessment protocol that is accurate, but easy enough that nurseries or botanic gardens could reasonably do it. That will be continuing into 2009. It is unclear what the future for PlantRight will be after 2009, but it is expected that it will carry forward in one form or another. Learn more from the website at www.plantright.org.

### Case Study 2: Washington Horticultural Invasives Prevention (WA-HIP)

In 2003, the Washington Invasive Species Coalition chose a pilot project working with the Washington State Nursery and Landscape Association (WSNLA). WSNLA appointed a task force and decided that the first project would be testing the concern that if nurseries did not sell certain invasive species, their profits would fall. A key concern of the task force, now renamed WA-HIP to coincide with the California effort, was that the species chosen were truly invasive. A rigorous procedure modeled after the NatureServe methods was developed and approved by the WSNLA members. Five species were selected for the project and several safe alternatives were identified. After much searching, five nurseries selling a general inventory agreed to be part of the project. The results over a three month period showed that sales of the invasives went down and sales of the alternatives were up. Nursery personnel reported that customers appreciated being informed of the invasive status of the species they requested and often bought the alternatives. Following this project, a 32-page booklet of 16 invaders in western Washington and their alternatives was developed and approximately 35,000 copies have been given away. All WSNLA member nurseries received them; in some cases receiving several boxes. An eastern Washington version is now in print. They have been observed in common use in many nurseries.

Beyond the printing budget, much of which came from a foundation that supports environmental printing, this project was not well-funded. Consequently, it did not have the ability to meet as frequently or include field trips. Despite the current lack of funding, however, the group continues to meet and discuss issues. Members have gained trust and respect for each other.

### Lessons Learned

The composition of the group is very important. The Cal-HIP program includes more than nurseries and this has been very beneficial. The commercial sector does not feel singled out and is therefore less defensive. In addition, the people selected to make decisions are very important. They should be respected by others, willing and able to communicate with their peers.

Once the objectives of the group are established, the tools develop the tools to achieve the goals. Environmentalists and ecologists have the expertise to help them do this. They may need help establishing which species should be targeted and in finding funding to pursue the objectives.

The most important lesson is that the stakeholders come from perhaps very different points of view and it will take time and patience on everyone's part to achieve consensus. The stakeholder group may need to meet several times for trust to be established and to understand cultural contexts. Some members of the stakeholder group and their fellow horticulturists may be in different stages of moving through the stages of grief to acceptance and will need time. Several projects in the United States and Australia, however, have demonstrated that working together at a moderate pace achieves worthwhile results.

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# Student Paper Contest

## Ecological Remote Sensing of Invasion by Perennial Pepperweed

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### Abstract

Remote sensing can address a variety of ecological questions. We present three ecological applications of remote sensing to study invasion of the San Francisco Bay/Sacramento-San Joaquin River Delta by *Lepidium latifolium* (perennial pepperweed). *Lepidium* is a noxious Eurasian weed aggressively expanding in the western US; understanding the ecology and management options for this weed are priorities. Hyperspectral imagery was used to map *Lepidium* in several sites annually over 2004-2007. Annual distribution maps allow quantification of *Lepidium* spread and dispersal on Bouldin Island, existing infestations doubled in size from 2004-2007 and a new infestation grew 35-fold, dispersing up to 226m from existing patches. We generated susceptibility models for *Lepidium* at the Rush Ranch Open Space Preserve with data extracted from hyperspectral and LiDAR datasets. *Lepidium* occurrence at this site is primarily a function of the distances from channels and uplands. Finally, imagery of Rush Ranch and Cosumnes River Preserve revealed substantial spatiotemporal variation in *Lepidium* phenology. Remotely-sensed variables explained 33-56% of the spatial variation in phenology and interannual variation at the Cosumnes River Preserve was closely related to hydrology. Our results highlight the importance of microtopography and water availability to *Lepidium* distribution and phenology.

### Introduction

Researchers and managers are increasingly embracing remote sensing, especially hyperspectral remote sensing, to map invasive plants (Lass et al. 2005). But although these maps can be used for ecological research, further informing management, they generally are not. We used remotely-sensed distribution maps of *Lepidium latifolium* (perennial pepperweed), a noxious Eurasian wetland/riparian invader that has recently become prominent in California, to predict potential habitat, quantify spread and understand variation in phenology of this species. This research can inform control efforts in space and time, identifying invasible sites prioritizes them for monitoring and eradication; knowing how weather influences spread can determine the importance of control in particular years and variation in phenology influences the effectiveness of both monitoring and control activities.

### Methods

Hyperspectral imagery was acquired in June 2006 at Rush Ranch (RR) and annually in June-July 2004-2007 at Bouldin Island (BI) and Cosumnes River Preserve (CRP). *Lepidium* was mapped with each image date of RR and BI (Andrew and Ustin 2008) and with a comprehensive field inventory at CRP. Remote sensing accuracies were very good for four maps (~90%) and fair for one (75%).

Presence/absence records were extracted from the *Lepidium* map of RR for distribution modeling with aggregate classification trees. Predictor variables – topography and distances to channels and uplands – were derived from a high-resolution LiDAR (light detection and ranging) DEM (digital elevation model) and the hyperspectral image. Infestation area and distance from a previous year's patch were determined from the distribution maps of three subsites on BI. Spread was related to precipitation. At RR and CRP, a spectral phenology index was developed. Logistic regression related phenology to topography and distances from channels, uplands, trees and the patch edge. Temporal variation in phenology at CRP was related to precipitation and streamflow.

## Results and Discussion

Distribution modeling identified 25% of RR (219 ha) as susceptible to invasion, only 5% of which is currently occupied by *Lepidium* (Figure 1). Distances to uplands and channels were overwhelmingly important to *Lepidium* occurrence. *Lepidium* is expected to occur within 30 m of channels or 35 m of uplands. However, there is an interaction between these terms, predicted distribution extends to 150 m from uplands when channels are relatively nearby. Topography was unimportant to *Lepiium* distribution, which is unexpected since marsh topography proxies inundation duration and frequency, and associated anoxia and salinity stresses, influencing community zonation (Pennings and Callaway 1992). Yet elevation clearly is an important correlate of *Lepidium* habitat, but is subsumed within distance to channel. Distance to channel has been found to be strongly predictive of wetland communities in a California salt marsh (Sanderson *et al*. 2000). *Lepidium* tends to colonize the natural levees along channels.

These results reveal that *Lepidium* selects habitats that minimize the stress associated with wetlands. The marshland-upland margin is expected to have a greater terrestrial influence than sites deeper within the marsh. When it occurs in the marsh, *Lepidium* tends to be found on the relatively high ground along channels, allowing it to avoid inundation

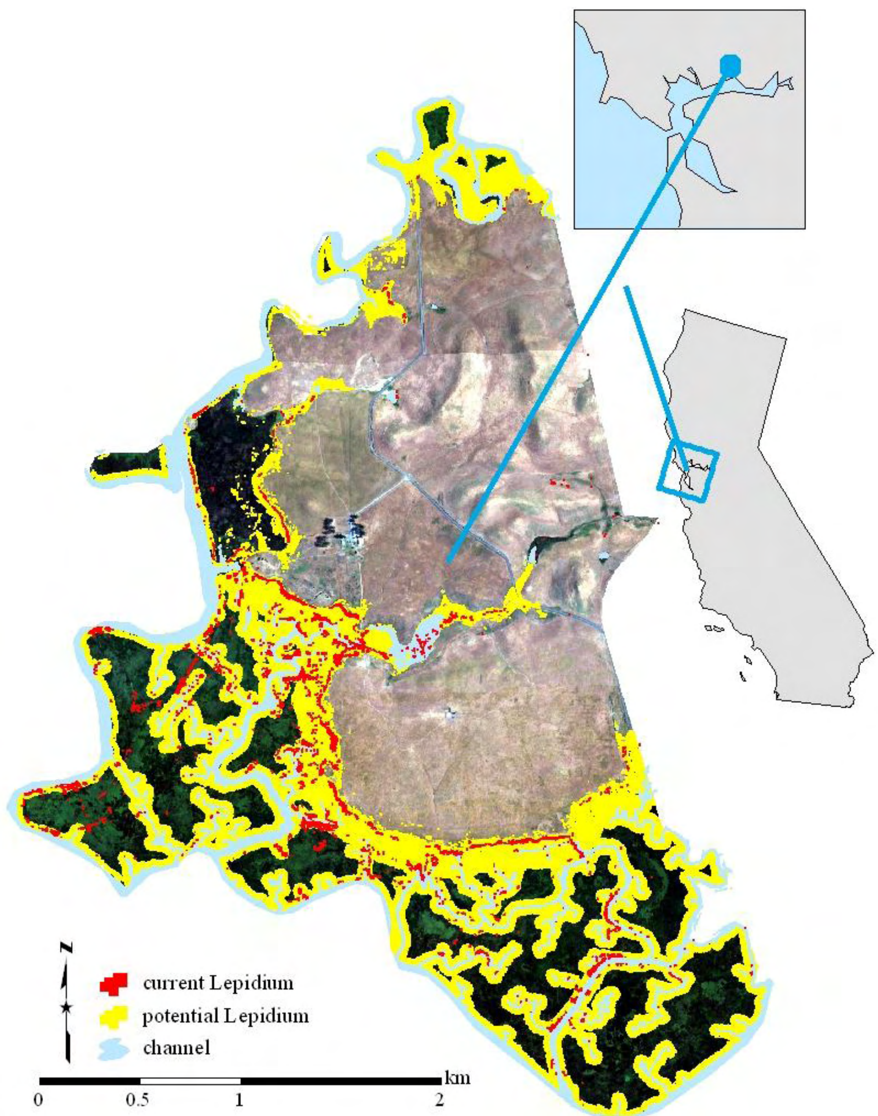


Figure 1. Current and predicted distribution of *Lepidium latifolium* at Rush Ranch

and anoxia stress. *Lepidium* possesses adaptations to both salinity (Blank and Young 2002) and inundation (Chen et al. 2005), so perhaps it is less competitive under these conditions.

*Lepidium* underwent dramatic spread from 2004-2007 on BI (Figure 2). The infestation spread linearly at sites with established populations (bridge, levee; Figure 2a & c), both of which doubled in area over the study period. At a site newly colonized during the study (western mesic; Figure 2b), *Lepidium* showed exponential growth; the area infested more than tripled each year, resulting in a 35-fold increase overall. Dispersal varied by year and site (Table 1).

The extremely rapid spread of the nascent population underscores that *Lepidium* infestations are a severe threat and can dominate a site very quickly. Eradication should focus on small satellite populations to curtail such exponential spread (Moody and Mack 1988).

Deviations from expected infestation area were negatively correlated with precipitation (Figure 2d), suggesting that spread is enhanced in dry years and slowed in wet years. However, this effect is subtle; *Lepidium* spread each year, regardless of weather conditions. More extreme conditions than experienced in 2004-2007 may have stronger impacts on spread; temperature and windiness may also be important and remain to be tested. Another consideration is that mapped distributions may correspond to previous years' spread due to sensor limitations. Positive and negative trends were found with springtime precipitation in years t-2 ($p=0.08$) and t-3 ($p=0.06$), respectively. Longer time series or data on the minimum detectable patch age are needed to determine the appropriate lag.

At RR and CRP, imagery detected spatial phenological variation. Observed stages were early flowering, peak flowering and fruiting (RR); and vegetative, flowering and senescent (CRP). At both sites, advanced phenologies were associated with the interior of patches, lower convexities, shallower slopes and higher elevations (RR: $R^2=0.33$, CRP: $R^2=0.56$), suggesting influences of intraspecific competition (Schmitt *et al*. 1987) and water availability (Chiariello 1989, Van der Sman et al. 1992). Interannually, phenology at CRP tracked hydrology. Five distinct trajectories

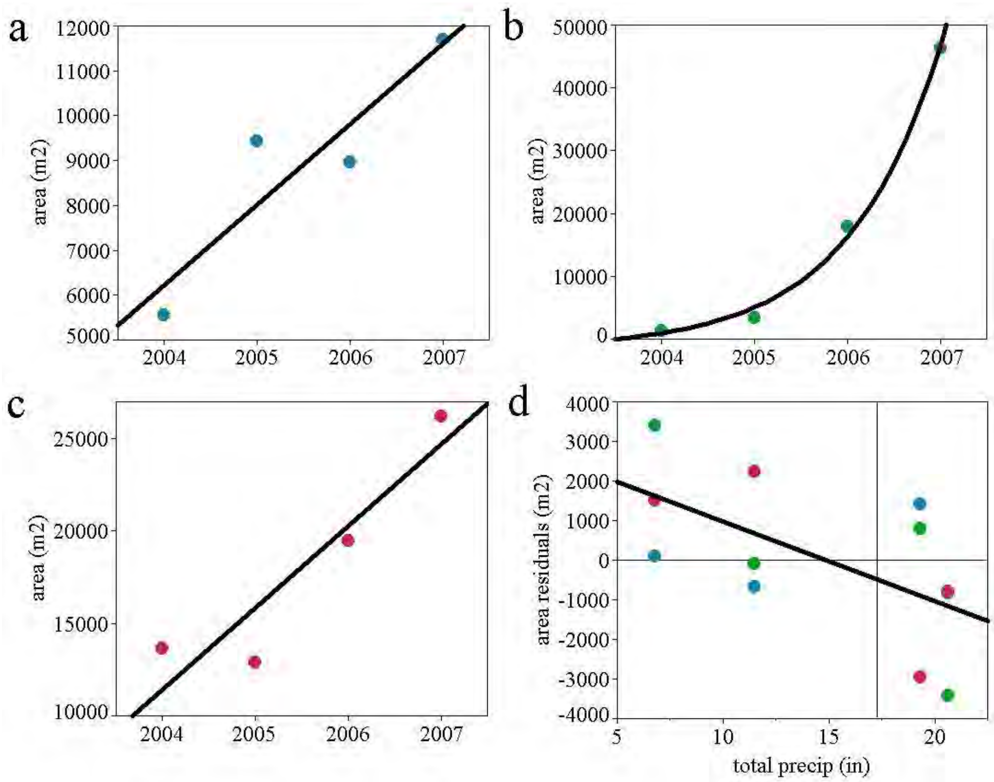


Figure 2

Area of Lipidium infestation on Bouldin Island as mapped from hyperspectral image data in 2001-2007 at the a) bridge, b) western mesic and c) levee subsites. In d) the residuals from the fitted linear (a, c) and (b) models are plotted against total precipitation in the preceding water year. Point colors are consistent with sites in a-c. Reference lines indicate zero residuals (ie., spread matched expectations) and average precipitation (17.28 in.). Positive residuals indicate greater spread than expected and vice versa.

| | 2004-2005 | 2005-2006 | 2006-2007 |
|---|---|---|---|
| Bridge | 16±18 [78] | 5±4[25] | 20±23[84] |
| Western mesic | 58±51[226] | 15±14[86] | 19±16[87] |
| Levee | 9±9[57] | 17±19[108] | 10±7[51] |

Table 1

Lepidium dispersal (mean±st. dev. [max]; m) by subsite and year at Bouldin Island

were observed, indicating that the degree to which phenology differs between years depends on site conditions as well as region-scale hydrology (Figure 3).

Phenological traits may contribute to *Lepidium*'s invasion success. Summer flowering is rare in Mediterranean climates and strongly associated with invasiveness (Lloret et al. 2005). *Lepidium*, a late-flowering species, may be taking advantage of this empty temporal niche. Additionally, phenology can control species distributions (Morin et al. 2007). Responsiveness of *Lepidium* phenology to environmental conditions may mediate the wide breadth of habitats *Lepidium* invades.

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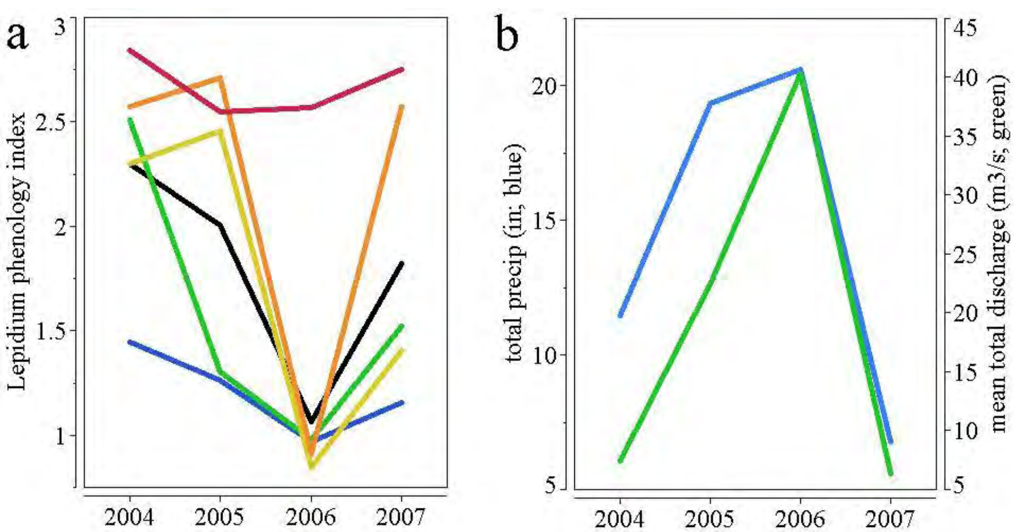


Figure 3

a) Average interannual variation in remotely-sensed Lipidium phenology at Cosumnes River Preserve for five distinct phenological trajectories (in colors) and for all Lepidium (black). For reference index vaules for vegetative, flowering and senescent stages are around 1.0, 1.5 and 3.0 respectively.

b) Total water year recipitation (blue) and discharge of the Cosumnes River (green), 2004-2007

# Using Airborne Remote Sensing to Map Sweet Fennel on Santa Cruz Island

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## Abstract

Santa Cruz Island (SCI) is the largest of the Channel Islands off the coast of southern California. Nearly all feral mammals have been removed from the island and invasive plant control has begun as well. In August 2007 the Carnegie Airborne Observatory (CAO) *beta* system surveyed the island, coincident with the blooming period for sweet fennel (*Foeniculum vulgare*), the most prevalent invasive plant on SCI. The CAO *beta* system combines the NASA Jet Propulsion Laboratory's Airborne Visible/Infrared Imaging Spectrometer with a light detection and ranging (LiDAR) sensor and an integrated navigational system. Together these sensors allow for the development of high resolution, high fidelity data products for vegetation structure, species composition and underlying topography. On SCI, known areas of dense fennel were used to train the CAO data to classify areas as likely to have fennel infestations. Field reconnaissance then identified which areas were correctly classified and which were false positives. This data was compared to a recent field-based invasive plant mapping effort for both accuracy and precision. We conclude that systems like the CAO can make valuable contributions to protected areas' invasive plant mapping programs.

## Introduction

The California Floristic Province, one of five Mediterranean-type ecosystems on the planet, spans from southern Oregon to Baja California and hosts a wide variety of habitat types, from grassland to chaparral to redwood forest. Only 24.7% of the original vegetation is left and it continues to be threatened by urban development, agriculture, pollution, climate change and altered fire regimes (Conservation International 2007). As the population in California continues to grow, demand will increase for open spaces and the ecosystem services they provide, as will impacts to those spaces that are preserved (Westrup 2006). Developing tools to quickly, accurately and inexpensively monitor landscape-level variation in these systems will foster better management and more precise valuations.

Recent developments in remote sensing technology have greatly increased the resolution of images captured, the range and number of spectral bands that are recorded and the types of data considered. Hyperspectral images capture broad ranges of wavelengths of light in small increments that may be used to quantify and map biophysical properties (Ustin *et al*. 2007). When this information is combined with active remote sensing techniques like light detection and ranging (LiDAR), measures of vegetation structure can be combined with hyperspectral data to create three dimensional representations of a system (Asner *et al*. 2007). These spatially accurate, highly detailed models can be analyzed in an automated manner, yielding results that are comprehensive and repeatable.

In August of 2007 the Carnegie Airborne Observatory (CAO) *beta* system, a remote sensing system that combines the NASA Jet Propulsion Laboratory's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) with a lidar system and an integrated navigational system, surveyed Santa Cruz Island (SCI), coincident with the blooming period for sweet fennel (*Foeniculum vulgare*). The objective for this project was to test whether the CAO could correctly identify fennel on SCI. A combination of field reconnaissance and previous mapping work on the island (Aerial Information

Systems 2007, ProHunt 2008) allowed us to validate the remote sensing classification across the island.

## Methods

SCI is the largest of the Channel Islands off the coast of southern California. It is owned by The Nature Conservancy and the National Park Service. This 96 square-mile island is home to twelve endemic species. Nearly all feral mammals (mostly sheep and pigs) have been removed from the island and now invasive plant control has begun. Sweet fennel is one of the most widespread invasive plants on the island, occupying many of the disturbed areas, but some wildlands as well (ProHunt 2008).

Data products from the CAO *beta* system – georectified raster images of ground topography (0.5 m resolution), vegetation height and spectral radiance in 224 bands with wavelengths ranging from 400 to 2500 nm (2.2 m resolution) – were used to identify areas of potential fennel infestation using ENVI 4.3™. First, areas that were obviously not fennel were masked. This included bare ground, clouds, water and anything more than three meters tall. The remaining spectra (pixels) were then classified using a spectral angle mapping procedure where a small, dense area of fennel was identified by hand (Figure 1) and then those training data were averaged and treated as a vector with a dimensionality equal to the total number of bands. Each pixel in the image was then compared to this vector and pixels closest to the training data were classified as fennel. In addition, training data were taken from areas that were obviously misclassified and used in the algorithm. This process was done iteratively to develop a map of fennel that most closely matched field observations (referred to below as the "CAO map").

Previous hand-mapping projects included two data sets. First, a vegetation map completed in 2007 (Aerial Information Systems 2007) identified polygons of dense fennel, assigning them to a "Fennel Mapping Unit" vegetation class and also identifying other vegetation polygons with some fennel cover. In addition, a 2007 invasive plant mapping project (ProHunt 2008) mapped points and lines indicating areas of fennel infestation and a percent cover class. Total mapped area of fennel was calculated by multiplying all of these areas by their respective mean percent covers and summing the results. Areas that were identified as fennel by the CAO map but that were not mapped as fennel during previous hand mapping campaigns were visited in August 2008 to determine whether or not fennel was actually present.

## Results and Discussion

The total hand-mapped area of fennel, combining both data sets, was calculated to be 467 hectares (ha). The CAO map identified approximately 330 ha on SCI that were spectrally similar to a known area of fennel (see Figure 1). The Vegetation Map (Aerial Information Systems 2007) delineated 283 polygons with more than 10% fennel cover.

Photo: Kyla Dahlin, August 2007

Figure 1

The area behind the chapel was used to train remotely sensed data

Of these 283 polygons, 217 (76.7%) contained some fennel as identified in the CAO map. In these 217 polygons, however, only six had more than 10% cover according to the CAO map. Unfortunately, the second, more comprehensive hand-mapping effort (6) did not delineate patch boundaries (approximate dimensions were included in an attribute table), so quantitative, spatial comparisons of the two methods were not possible. However, visual inspection showed that in many places the CAO map successfully identified fennel patches (Figure 2).

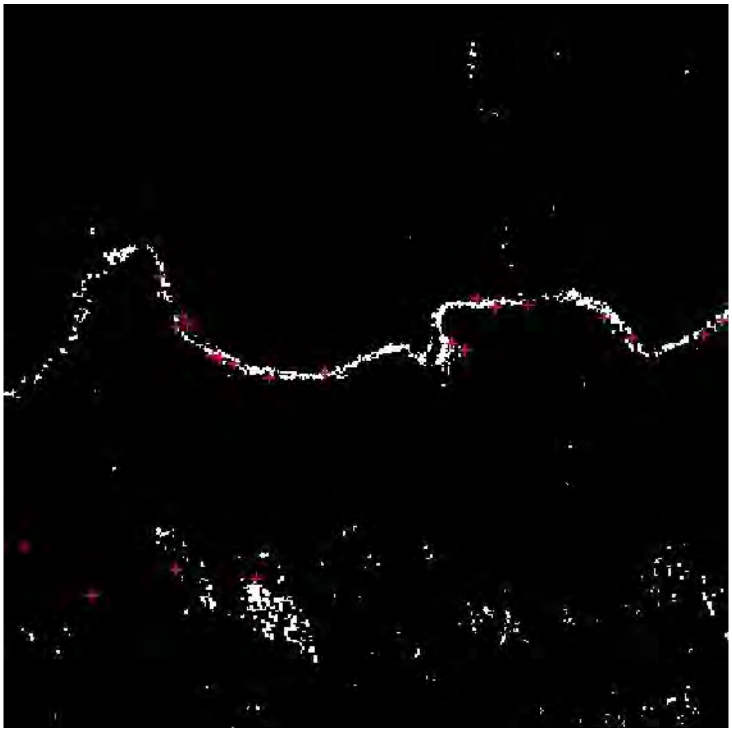

Figure 2

A subset of the CAO map (white pixels = fennel) along the creek near the center of the island, with points (red +'s) of fennel mapped by ProHunt (6)

Of the 27 locations visited in August 2008, where the CAO map indicated a high probability of fennel but none was hand-mapped, only two actually had fennel. Field observations suggested that the CAO algorithm most frequently misclassified mulefat (*Baccharis salicifolia*), a common native plant, as fennel. In addition, areas of fennel with a high percentage of dead material were often not classified as fennel by the algorithm.

Field validation taught us that the hand-mapped data sets were very thorough. As a result, subsequent iterations of the remote sensing algorithm have focused on developing a map that reflects both our observations in the field and the hand-mapped efforts.

Hand mapping vegetation is a time-consuming, expensive, and subjective process. Even exceptionally thorough studies like those on SCI are difficult to compare over time, especially if methods and personnel change. Though remote sensing is influenced by atmospheric changes and the choices of the researchers, data processing is repeatable and transparent. In addition the raw images serve as a snapshot in time and can be saved for future studies. It was the intent of this study to show that airborne remote sensing could be used as one of the many tools in invasive species management. We conclude that, indeed, remote sensing is an excellent way to identifying potential areas of infestation. However, using the above techniques, many areas were still misclassified and the total area of fennel was underestimated. A more successful approach would have been to have data processing capabilities in the field so that new algorithms could be run as more information was gathered. For example, once a "false positive" was found, that information could have included in a new classification, improving the CAO map iteratively.

Future studies will focus on more refined classification methods and more integrated use of the lidar data. Additional surveys by the CAO could capture plants during different phenologies and record how vegetation changes over time.

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# Prioritizing California's A-rated Weed Populations for Eradication

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## Abstract

California has many pioneer weed infestations worthy of eradication, but too few resources to respond to all. Traditionally, weed lists guide eradication efforts in the state. However, species evaluation systems have limitations when applied to prioritizing individual populations for eradication. Therefore, the California Department of Food and Agriculture's (CDFA) Integrated Pest Control Branch developed a science-based, transparent, decision-making tool to help prioritize weed *populations* for eradication using the Analytical Hierarchy Process. This ranking tool assesses the relative impact, potential spread and the cost and feasibility of eradication. This tool will help land managers systematically target weed infestations by putting their limited resources into populations known to cause the highest impacts and are most feasible to eradicate.

## Introduction

When a potentially noxious weed population is discovered early, eradication, defined as the elimination of all individuals and their propagules from a defined area, is the most cost-effective strategy, as opposed to suppressing the population indefinitely (Rejmánek and Pitcairn 2002). The California Department of Food and Agriculture (CDFA) is faced with the question of which approach should be employed to minimize future spread and impacts using limited budgets.

Traditionally, weed lists have guided eradication efforts in California (e.g. species designated "A" and "Q" on the CDFA Plant Pest Rating List and, more recently, species designated High or Alert in the Cal-IPC Inventory). However, all-or-nothing species evaluation systems have limitations when applied to prioritizing individual populations for management. Hiebert (1997) and Randall *et al.* (2008) provide summaries of existing weed risk assessment and prioritization systems. These systems rank each species, which assumes uniform impact, potential for spread and feasibility of control across all occurrences of the species. A prioritization tool that considers each infestation separately for eradication is needed.

Here we propose a method to prioritize invasive, pest plants for eradication. This prioritization tool assesses the relative impact, potential spread and the cost and feasibility of eradication for individual populations. Where it differs from previous protocols is that it incorporates a spatially explicit, infestation-centered approach, using GIS layers that correlate to high-value assets and vectors of spread.

## Building the Weed Population Prioritization Tool

***Step 1. Identify high-priority species.*** In this study, the CDFA's A-rated weeds were used to develop the model.

***Step 2. Map the weeds*** Tracking the location and extent of weed populations is essential to running the populations through this prioritization tool. We compiled this information in ArcGIS from the CDFA's A-rated Weed Database.

***Step 3. Identify ranking criteria*** Many factors contribute to the decision to manage weed infestations. Our goal was to identify criteria that contributed most to the program goals. After reviewing the scientific literature and hosting discussions with experts, the major and sub-criteria chosen were:

*Impact* assess relative impact to wildlands, agriculture, and human health. Estimate the regional value of the site via its proximity to agricultural commodities at risk, rarity occurrences of threatened and endangered species, important recreation areas (national and state parks) and US Forest Service land (due to limited control options).

*Invasiveness* assess the likelihood of spread based on maximum rate of spread in California, distance to propagule sources of conspecific populations and proximity to vectors of spread: major roadways, rivers, and mining operations.

*Feasibility of Eradication* assess the feasibility of an eradication project based on population size, reproductive ability (seed set, vegetative reproduction, seed longevity, lengths of juvenile and reproductive phases), detectability, accessibility, control effectiveness and cost.

***Step 4. Assign weights using the Analytical Hierarchy Process** (AHP)* This is a mathematical decision-making method that utilizes experts' judgments to quantitatively break down a complex decision into its component parts (Saaty 1980). First, we arranged the decision-making criteria into a hierarchy (Table 1). Fifteen experts around the state were surveyed, their responses were averaged, and the weights were calculated (Table 1). This process has been used in Australia (Weiss and Iaconis 2002) and by the Santa Monica Mountains National Recreation Area (Althoen *et al*. 2007).

Table 1

Criteria were arranged in a hierarchy and major and sub-criteria weights were calculated via the Analytical Hierarchy Process.

| Major Criteria | |
|---|---|
| **Impact** | **0.378** |
| Wildlands | 0.336 |
| Agriculture | 0.238 |
| Humans | 0.113 |
| Regional Site Value AKA Nearness to High-Value Assets: | 0.313 |
| *Crops/Rangeland* | 0.261 |
| *Rarity Occurrences* | 0.518 |
| *Recreation Areas* | 0.100 |
| *USFS Land* | 0.121 |
| **Invasiveness** | **0.229** |
| Propagule Source | 0.254 |
| Spread Rate | 0.360 |
| Nearness to Spread Vector: | 0.386 |
| *Major Roadways* | 0.333 |
| *River Systems* | 0.425 |
| *Gravel Operations* | 0.243 |
| **Feasibility of Eradication** | **0.393** |
| Size | 0.253 |
| Reproduction | 0.177 |
| *Seed Set* | 0.159 |
| *Vegetative Reproduction* | 0.154 |
| *Seed/Propagule Longevity* | 0.448 |
| *Juvenile Phase* | 0.132 |
| *Reproductive Phase* | 0.106 |
| Detectability | 0.125 |
| Accessibility | 0.149 |
| Control Effectiveness | 0.190 |
| Control Cost | 0.105 |
| *Driving Time* | 0.132 |
| *On-Site Control* | 0.339 |
| *Follow-up* | 0.347 |
| *Special Considerations* | 0.182 |

***Step 5. Gather information and score criteria*** We gathered information via the Cal-IPC plant assessment forms (Cal-IPC 2006), *Weeds of California and Other Western States* (DiTomaso and Healy 2007), the CDFA Encycloweedia (CDFA 2008) and other published and Internet resources. Expert opinion was relied upon for weeds with little published information. Criteria at terminal nodes in the hierarchy were scored on a scale of 0 to 10 with emphasis placed on high-priority attributes of a weed species or population.

***Step 6. Calculate overall priority score and rank populations*** by multiplying each score by the corresponding weight for that criterion and adding the weighted criteria scores. We tested the prioritization tool with a random sample of 100 populations stratified by 25 species and ranked the populations in order of overall priority.

***Step 7. Assess resource availability and choose eradication projects*** External circumstances may need to be considered at this point, e.g. landowner cooperation or socio-political environment for control. A land manager may choose to focus 60% of the budget on the highest priority infestations, and spend the remaining budget on populations in the vicinity of or en route to those first tier infestations, thus maximizing the efficiency of staff time. Populations ranking lower may be targets for containment or biological control.

## Conclusions

The range of scores was 3.7 to 7.7 out of 10 possible points. Preliminary findings indicate that conspecific populations do not necessarily group together in the final ranked output, which supports a system where occurrences of the same species should not be given the same priority for management. This tool will help land managers systematically target weed populations by putting their limited resources into populations known to cause the highest impacts and are most feasible to eradicate. A preliminary model validation analysis is in progress.

The prioritization process results in a prioritized list of infestations based on a transparent, analytical system and a record of the decision-making process, which will help to justify program authorization and funding (Hiebert 1997). Disadvantages of using a prioritization tool are that it is time-consuming and there are data availability and quality issues. However, the protocol is adaptable to many different scales and can be revised based on experience and recommendations from users and expert reviewers.

California is so large that regional eradication achieves clear benefits. Weed prioritization protocols are now becoming a common way to focus activity and resources. However, from the standpoint of eradication programs, species-level priorities do not allow for regional and population-level considerations. The prioritization scheme can be designed to look at eradication of discrete infestations. By strategically targeting weed populations using the limited resources available, we minimize future spread and mitigate future impacts.

## Acknowledgements

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## Prescribed Fire and Exotic Plant Effects on California Grasslands

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### Abstract

California grasslands have been invaded by a suite of Mediterranean annual grasses for over 200 years. The effects of this conversion from a native bunchgrass and annual forb grassland to exotic, annual grassland have negative impacts on native vegetation and wildlife. However, there is less information about the impacts of exotic invasions on soils and if those impacts can be reversed. We tested the effectiveness of prescribed fire to control density of exotic grasses. Our objectives were: 1) examine the effectiveness of spring, prescribed burns in controlling exotic grasses, 2) determine an optimal burn regime to reduce exotic grasses and release native plant species and 3) determine if soil chemistry is responding to reduced exotic grass caused by burning. Total carbon, total nitrogen, phosphorus, $NO_3$ and $NH_4$ were not different in soils from differing burn years. Prescribed burns reduced exotic grass cover, while exotic and native forbs increased in the absence of exotic grasses. However, exotic grass cover returned to pre-burn levels within five years indicating a five-year burn frequency may be optimal to initially gain control of the exotic grasses.

### Introduction

California grasslands have been extensively invaded by exotic annual grasses and are subject to restoration efforts using fire (Gillespie and Allen 2004). The impacts of invasive grasses have been relatively well studied on vegetation, but less is known about belowground effects. Exotic grasses may change nutrient cycles, alter microbial communities, increase fire intensity and frequency, change litter quality and quantity, displace natives and decrease biodiversity (Ehrenfeld 2003). Exotic grasses can limit germination and establishment of native perennials (Moyes *et al*. 2005). Altering the natural fire cycle of grasslands has negative consequences to grassland ecosystems (D Antonio and Vitousek 1992). However, reintroduction of fire with the appropriate timing could reduce exotic grass cover and aid in native plant restoration efforts. Prescribed fires used for exotic plant species control are generally low in intensity (Ubeda *et al* 2005). Because grassland fires move rapidly and create low levels of heat, it would be expected that grassland prescribed burns would have low impacts on soils that are short lived.

Restoration burns at the Santa Rosa Plateau are timed to coincide with grass phenology such that burns are conducted when grasses are holding seed on standing biomass. This approach allows burning of exotic seeds before they reach the safety of the soils, thereby reducing the exotic grass seed bank (Gillespie and Allen 2004). Standing seed can be reduced by 96% and overall grass biomass and stand density can be reduced by spring burns. Spring, prescribed burns can allow native perennials to replace exotic annuals (Moyes *et al*. 2005), but without continued management this will not last (Wills 2000).

Our objectives were to 1) examine the effectiveness of spring, prescribed burns in controlling exotic grasses, 2) determine an optimal burn regime to reduce exotic grasses and release native plant species, 3) determine if soil chemistry is responding to reduced exotic grass caused by burning. In order to accomplish this we utilized two different methods. The first is a one time sampling across a chronosequence of areas burned over the last 20 years. The second is a long-term data set collected from one burn unit over a six year period along permanent transects. We intended to address changes in species composition with the latter and to link above and below ground feedbacks with the former.

## Methods

The Santa Rosa Plateau Ecological Reserve is located in Murrieta, California (33°31° N, 117°15' W, 600 m a.s.l.). The reserve consists of 8,200 acres on which five habitats flourish, including coastal sage scrub, chaparral, oak woodland, vernal pools and grasslands. Soils are mainly basalt in origin. The climate is Mediterranean with cool, moist winters and hot, dry summers. Average annual precipitation is approximately 48 cm with the majority falling between November and April.

The reserve's grasslands are divided into 19 burn units. For the chronosequence method, we sampled from seven of these units using nine randomly located plots per burn unit. Plots were placed within similar soil types, aspect and slope. Plant species richness and cover were sampled at peak season. Soil core samples of 10cm depth were analyzed for total carbon and nitrogen, $NO_3$, $NH_4$, and phosphorus.

Data for the long-term method was collected along permanent 50m transects. Line-point intercept sampling was conducted at one m intervals during springs of 2001-2006. Plant species at each intercept were recorded. Only one burn unit had been sampled pre and post fire, therefore only results from that unit will be discussed here.

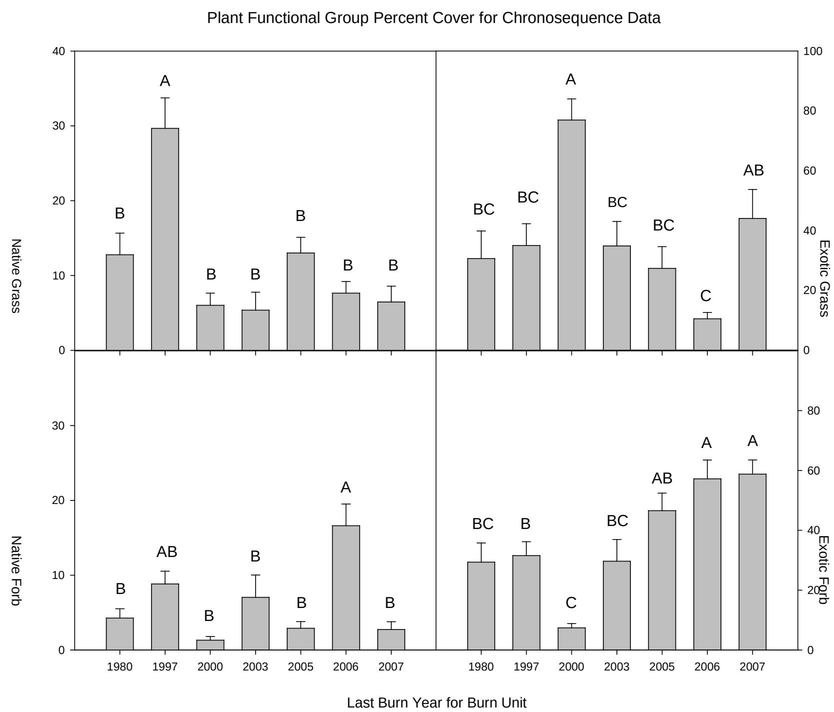
Vegetation and soil phosphorus were analyzed using ANOVA. The remaining soil chemistry data was analyzed using Kruskal Wallis due to the non-normality of this data.

## Results

***Chronosequence:*** Exotic forb, native forb and native grass percent cover and species richness for peak growing season were significantly different between burn units; however they did not follow discernable patterns (Figure 1). Exotic forb cover was significantly different between burn years with an increase of cover in those most recently burned (R2=0.540, P<0.0001) (Figure 1). Soil extractable nitrogen and phosphorus also did not differ between burn units in any discernible fire related patterns. Total nitrogen and carbon show peaks (1980, 2000) that are significantly different from the other burn years ($X^2=34$, $P<0.0001$ and $R^2=58$, $P<0.0001$), however, also show no fire related patterns (Figure 2).

Figure 1

Percent cover of functional groups (native forb, exotic forb, native grass, exotic grass) recorded during one sample date from multiple burn units of the grassland.



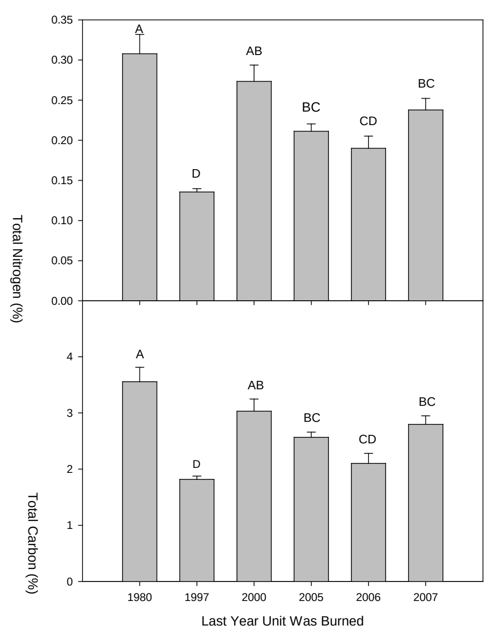




Figure 2

Total nitrogen and carbon by percent collected during the peak of the growing season from a chronosequence of burn units.

***Long-term data:*** Native forb percent cover was significantly higher in burn units more recently burned ($R^2$=0.53, P<00.1). Native grass and exotic grass cover was significantly different between burn years ($R^2$=0.450, P=0.0003 and $R^2$=0.660, P< 0.0001) showing an initial decrease following fire and an increase with time since past fire (Figure 3).

competition following removal of exotic grasses by fire. Because exotic forbs germinate earlier in the season than native species, it is possible that native species do not experience the same reduction of competition that exotic forbs experience. Instead of competing with exotic grasses, native compete with exotic forbs.

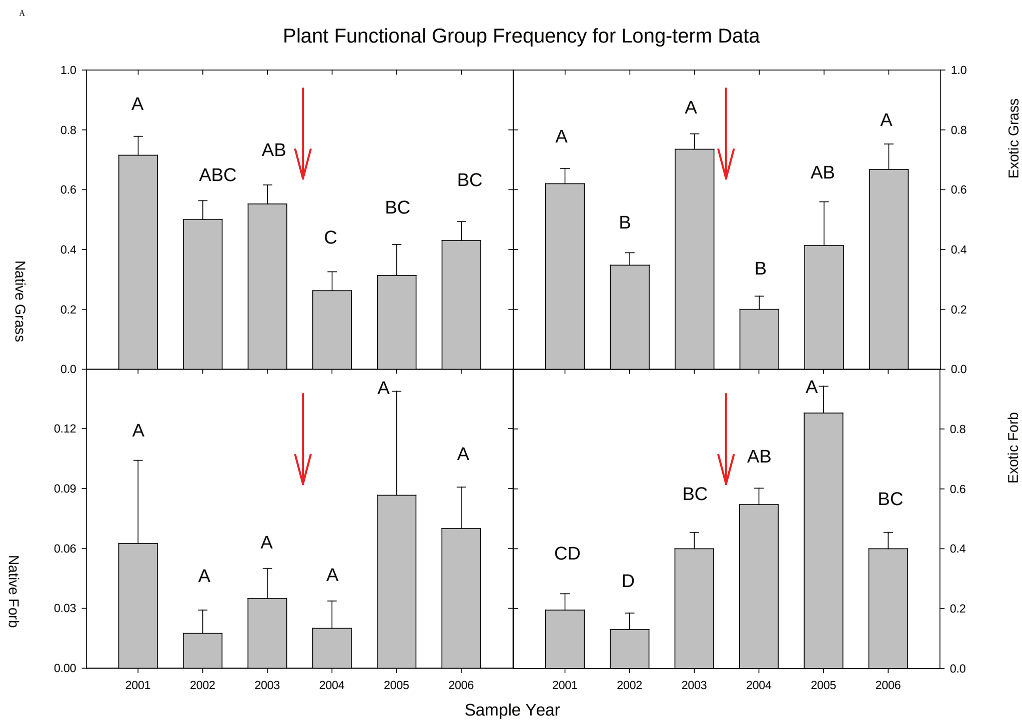



Figure 3

Frequency values for functional groups (native forb, exotic forb, native grass, exotic grass) recored along transects in one section (burn unit) over a six year period.

## Discussion

Southern California climate is notorious for its large interannual differences in timing and total amounts of precipitation. Minnich (2008) describes how timing of rainfall influences which species will become dominant. Years with early rain fall often lead to higher exotic forb cover, while late rains can lead to a more balanced community composition. The lack of fire related patterns in the chronosequence data indicate that differences between burn unit plant functional group percent cover is due to factors other than fire. These differences may be the result of annual differences in precipitation and/or precipitation patterns just before and following the prescribed burn. The higher native forb cover in more recent burns is likely due to a reduction of

Restoration fires at Santa Rosa Plateau Ecological Reserve are of low intensity and duration; therefore, they would be expected to have little impact on soils (Ubeda *et al*. 2005). The lack of differences in soil chemistry between burn units indicates that the fires cause no significant, long-term alteration of soil chemical properties. This being the case, any differences in soil chemical properties would be due to differences in percent cover of the exotic species and their feedbacks to soils. If prescribed burns reduced exotic cover, soil chemical properties would show a gradient of change over time since last burned. No such patterns of soil chemical properties were found indicating that neither the prescribed burns nor the exotic plant percent cover are altering the soil chemical pools of total carbon, total nitrogen, extractable nitrogen, or phosphorus.

Peaks in total carbon and nitrogen in the burn units last burned in 1980 and 2000 are likely explained as a result of gopher activity. Gophers burying the litter could increase both carbon and nitrogen levels in soil by increasing the organic matter content.

The long-term data showed patterns of change in plant functional groups in relation to time since last burned. Fire reduced exotic grass cover; however frequency of exotic grass returned to pre-burn levels within four years. Native and exotic forbs respond with increased frequency after fire followed by a decline as exotic grasses recovered. These results indicate that forb species are experiencing a release from competition with the exotic grasses during the first years after fire. The limited window of response of native forbs may be both the result of reinvasion of exotic grasses and increased competition with earlier germinating exotic forbs.

Managing exotic species in California grasslands continues to be a challenge for land managers. Prescribed burns have often been used with high levels of success. Since pre-fire exotic grass frequencies returned within four years of the burn, burning every four or five years might reduce exotic grasses while allowing for the natives to persist. While increases in native forbs do not persist over time due to reinvasion of the exotic grasses, prescribed burns can provide an opportunity for these native species to set seed often enough to maintain a seed bank.

A secondary result of this project is a confirmation that long-term data sets are far more effective in describing patterns of change in plant communities over time. While the long-term data was of a courser scale than the percent cover data of the chronosequence, the length of time over which the data was collected proved to be more important in describing the plant community.

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## The Role of Resource Heterogeneity on Native Plant Response to Invasive Plant Removal


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### Abstract


The purpose of this study was to evaluate the response of native annual plants to the removal of invasive annual grasses and forbs in two contrasting microhabitats, resource poor shrub interspaces and relatively resource rich fertile island understories. The study took place over four years in Coachella Valley, California. Four sites were used that varied in their abundances of native annuals, invasive annual grasses, *Erodium cicutarium* and *Brassica tournefortii*. Invasive grasses were removed with Fusilade-II®, a 'grass-specific' herbicide, and invasive forbs were weeded by hand. We found that invasive plants were more abundant in understory than interspace microhabitats and that competition intensity was higher in the understory. Native species richness was greater in the interspace but had the largest relative increase in the understory once

invasives were removed. We then compared the removal of all invasive plants (R), as described above, to a treatment utilizing only Fusilade-II. At sites where the invasive species composition was mostly grasses and *E. cicutarium*, Fusilade-II worked as effectively as R since it is also lethal to *Erodium* species. Use of this herbicide should be relevant to other vegetation types invaded by exotic annual grasses and *Erodium*. Finally, while our results suggest prioritizing resource rich microenvironments for invasive species control, this may not always be optimal. For example, interspace grass invasions in arid shrublands connect widely spaced shrubs, fueling disastrous wildfires. Where this occurs, targeting interspaces may be more important. Clearly, site-specific factors and various ecosystem processes must be considered when controlling invasive plants.

## Introduction

This study evaluates the difference in competition intensity and native species richness between relatively resource rich (shrub understory) and resource poor (interspace) microhabitats based on the response of native annual plants to complete invasive species removal. The null hypotheses are 1) invasive species abundance will not vary between microhabitats, 2) competition intensity will not vary between microhabitats and 3) native richness is equal between microhabitats and will increase proportionately the same once invasives are removed.

We also compare the results from the invasive plant removals with a treatment only utilizing Fusilade II (Syngenta, Greensboro, North Caroline). Fusilade II (fluazifop-P-butyl) is a grass specific herbicide in the same herbicide family (Aryloxyphenoxy-propionate) as haloxyfop (Verdict® Dow Chemical). In a greenhouse experiment, haloxyfop was shown to cause mortality to plants in the genera *Erodium* and *Pelargonium* at the same rates used to kill grasses (Christopher and Holtum, 2000). We wanted to test the ability of Fusilade II to kill both invasive grasses and invasive *E. cicutarium* in the field. Control of exotic dicots when mixed with native dicots in natural assemblages is extremely difficult without non-target effects. A tool that reduces invasive grasses and forbs without negative consequences to native annual forbs would be very useful alone or as part of an integrated approach to restoring invaded communities.

## Methods

The study area was in western Coachella Valley, Riverside County, California. The four study sites used in the experiment, 'Grass', 'Filaree', 'Mustard' and 'Native', were named based on dominant annual species at time of treatment implementation. All sites were in creosote bush scrub vegetation. Two treatments were utilized in this experiment 1) the removal of invasive annual grasses with the use of Fusilade II, a 'grass-specific' herbicide, combined with the removal by hand of invasive forbs (R) and 2) the use of Fusilade II alone (F). The two treatments and a control (C) were implemented in a randomized, complete block design composed of twelve blocks. Plots were 8x8m and centered on a mature *Larrea tridentata* individual.

Control plots were left un-manipulated. The entire area of the R and F plots were sprayed with Fusilade II, at a rate of about 20ml/64m². Herbicide Helper® (Monterey Lawn and Garden Products, Inc, Fresno, CA) was used as a surfactant at the rate of 16ml/64 m². At all sites and in all years when treatments were implemented, plots were sprayed before grasses had reached flowering stage, as recommended by the manufacturer. Weeding of invasive forbs was done within a week of herbicide spraying. Treatments were implemented once in January 2005 at the Grass site. In January 2008, the experiment was replicated at the Filaree, Mustard and Native sites.

Biomass and phenological stage of *Schismus* spp. and *E. cicutarium* were recorded at treatment application time for every site from 12, 0.125m² (0.5mx0.25m) sampling frames in interspace habitat. Percent cover by species and species richness were measured in 0.5m² (1mx0.5m) sampling frames at peak flowering for four years following treatment implementation at the Grass site and once in 2008 for the other three sites, following their treatments. For interspace measures, two sampling frames were placed in the two corners of the plot least influenced by standing shrubs, fertile islands, ant mounds or small mammal disturbances. At the mustard dominated site, three interspace plot frames were used instead of two since interspace annual plant abundance was thought to be low in the sandy substrate, *a priori*. Sampling frames were also placed in the understory of the plot-central *L. tridentata* individual, on the north and south understories. Sampling frame locations within each plot were demarcated with wooden stakes. The competition index, RCI (Goldberg *et al*. 1999), was used to calculate competition intensity for both the interspace and understory based on the total cover of native annual forbs from C and R plots. Data was analyzed using ANOVA and LSD tests at $\alpha = 0.05$.

## Results and Discussion

***Hypothesis 1*** Significantly greater cover of invasive annual species was recorded in understory vs. interspace microhabitats. Greater invasive plant cover in the understory was maintained at all sites and in all years except at the native forb dominated site, which had scarce amounts of invasive plants.

***Hypothesis 2*** Values obtained from the RCI showed that competition by invasive annuals on native annuals is intense at all sites and in all years. However, RCI values for the native annual cover response to invasive annual removal between understory and interspace microhabitats was only significant at one site, the invasive mustard dominated site in 2008, where intensity was greater in understory microhabitat compared to interspace. At all other sites and in all other years there were no significant differences between microhabitats.

***Hypothesis 3*** Native annual plant richness was significantly greater in interspace than understory habitats at all sites and in all measurable years. Also, the relative increase in native richness in response to invasive plant removal was greater in understory than in interspace microhabitats, but only significantly so at the Filaree and Mustard sites in 2008. We found that while interspace microhabitat may have greater native richness, once invasive annuals are removed from both microhabitats a relatively greater increase in native richness occurs in the understory.

While the differences between microhabitats were not always significant, we reject all null hypotheses. Overall, these results suggest that resource rich microhabitat are relatively more invaded, experience more intense competition, and have greater native plant response once invasives are removed, assuming native propagules are not limiting in either habitat.

## Comparisons between C, R and F Treatments

At the Grass site in 2005, both R and F treatments equally reduced exotic annual grass cover, while only the R treatment was effective at reducing invasive annual forb cover and significantly increasing native forbs. For the other three sites in 2008, the F treatment worked as effectively as R at sites where invasive grasses and *E. cicutarium* were the primary invasive components. At the mustard site where *B. tournefortii* was the most important invasive plant, the F treatment was not as effective as R. Also, where invasive annuals are uncommon, such as the Native site, removal of invasives has no immediate effect. However, invasive control at early stages of invasion is much more efficient and effective than at later stages of invasion (Hobbs and Humphries 1995) so invasive control in native dominated sites may still be important.

At the Grass site in 2005, initial biomass of *E. cicutarium* at treatment application time was no different than at peak season. However, initial *Schismus* spp. biomass was significantly less than peak season biomass. At treatment application time, 70% ± 9.7%SE of *E. cicutarium* was flowering and/or fruiting. When treatments were applied in 2008, no *E. cicutarium* were in flowering and/or fruiting stage at any of the three new sites. Also, the biomass of both *E. cicutarium* and *Schismus* spp. were both significantly less at treatment application time than at peak season. Based on this study, it is clear that *E. cicutarium*, like grass species, is more responsive to Fusilade-II before inflorescence initiation. Because *Erodium* spp. germinate quickly with the first substantial rains and have a rapid phenology compared to most native annuals (Jennings 2001), herbicide application should be implemented very early in the growing season before *Erodium* spp. begin flowering if mortality is desired. Great care must be especially taken when treating sites with susceptible native plants.

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## Removing Exotic Annual Grasses from Coastal Dunes: Effects on Native Solitary Ground-Nesting Bees


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### Abstract


Exotic annual grasses are invading many of California's coastal habitats. In coastal dunes in Humboldt county, European hairgrass (*Aira praecox*), silver hairgrass (*A. caryophyllea*) and squirreltail fescue (*Vulpia bromoides*) are invading several microhabitats. Researchers at the Humboldt Bay National Wildlife Refuge Lanphere Dunes Unit have found that flaming exotic annual grasses with a propane torch is the most efficient and effective removal method. There is concern, however, that flaming may increase mortality of an important native pollinator, the Leafcutter bee (*Megachile wheeleri*), which builds shallow nests in areas invaded by exotic annual grasses. Plots were set up with a known number of bees buried at 2 cm, 5 cm, and 8 cm, the range of natural nest depth. Plots were either control, treated with a propane torch, or treated with a radiant heater, an alternative removal method thought to penetrate heat less deeply into the soil. Emergence was monitored and compared among treatment and control plots. Results indicate no decrease in emergence due to either treatment method. Overall emergence ranged from 26.7% – 21.0% for treatment and control plots, and temperature data showed low heat penetration by both the propane torch and the radiant heater. This is good news for land managers trying to restore our coastal dunes. It is important for managers to consider the effect of invasive plant management on native pollinators, which are essential for restoring and maintaining a functioning ecosystem.


### Introduction

Coastal dunes are some of the most threatened ecosystems in North America. Most dune systems on the Pacific Coast are fragmented and degraded due to development, recreation and invasive plants (The Nature Conservancy 1997). Restoration of coastal dunes has largely focused on removal of invasive plants, though relatively little is known about how exotic plants and their removal affect native pollinators of coastal dunes (but see Nyoka 2004). Native pollinators of endemic plants are often critical to their persistence (Kearns and Inouye 1997), so in order to preserve native plants and thereby native ecosystems, it is essential to maintain native pollinator populations as well (Buchmann and Nabhan 1996). The most important native pollinators of coastal dunes in California are solitary ground-nesting bees, so it is critical to understand how restoration techniques affect their nesting habitat.

A current focus at the Lanphere Dunes Unit of the Humboldt Bay National Wildlife Refuge is removal of exotic annual grasses, including European hairgrass (*Aira praecox*), silver hairgrass

(*Aira caryophyllea*) and squirreltail fescue (*Vulpia bromoides*). The native solitary ground-nesting Leafcutter bee, *Megachile wheeleri,* is strongly associated with the two hairgrasses (Gordon 2000). The Leafcutter bee is one of the most abundant pollinators in the Humboldt Bay dunes and is also associated with other less common native bee species. Removal of exotic annual grasses at Lanphere Dunes is most efficient and effective with a propane torch, in which the targeted grass species are incinerated by an open flame (Wear 2000). This removal technique may cause mortality of ground-nesting bees due to exposure to lethal temperatures (Nyoka 2005). An alternative thermal treatment, which uses a radiant heater fitted with a ceramic head instead of an open flame, promises to kill the grasses and penetrate heat less deeply into the soil. This study investigates the impact of thermal removal of exotic annual grasses on the Leafcutter bee, comparing the propane torch treatment to the radiant heater treatment.

## Methods

Nest sites were mapped during active nest-building in summer 2006. The nest cells were excavated during dormancy in the fall-winter 2006-2007 and buried in 15 1-m$^2$ plots. Nine nest cells were buried in each plot, with three buried at 2 cm below the soil surface, three at 5 cm deep, and three at 8 cm deep. Plots were treated in spring 2007, the time of year exotic annual grasses are treated. Five of the plots were treated with a radiant heater, five with a propane torch and five were control. Plots were treated for approximately two minutes, the typical amount of time needed to kill exotic annual grasses. After treatment, emergence cages were set up over the plots and emergence of adult bees was recorded for each plot throughout the summer. Concurrently, temperature loggers were buried at 2 cm, 5 cm, and 8 cm in typical nesting habitat and treated in the same manner as plots, in order to determine the temperature reached at burial depths. Contingency analysis was used to compare observed emergence rates among treatment and control plots.

## Results and Discussion

Of the 128 nest cells buried in plots, 31 emerged, a 24.2% emergence rate overall (see Table 1). The overall emergence rate seems extremely low, indicating an overall mortality rate of 75.8%; Gordon (2006) found that mortality of Leafcutter bee nest cells protected from mammal predation was between 12% and 58%. There was a high variance among plots, from 0% to 67% (mean = 25.6%, standard deviation = 19.0) (see Table 2). While it unclear why this experiment yielded such low emergence rates, it is clear that the emergence rate among the control plots was not very different from that of treatment plots. Contingency analysis showed that both thermal treatments had no impact on emergence ($X^2$ = 0.355724, d.f. = 2, p-value = 0.8371) (see Table 3).

| Treatment | Total # of Nest Cells | Total # Emerged Bees | Emergence Rate |
|---|---|---|---|
| Propane | 45 | 12 | 26.7% |
| Heater | 38 | 8 | 21.0% |
| Control | 45 | 11 | 24.4% |
| Overall | 128 | 31 | 24.2% |

Table 1

Emergence by Treatment

| Plot # | Treatment | Total # Nest Cells | Total # Emerged Bees | Emergence Rate |
|---|---|---|---|---|
| 1 | Propane | 9 | 0 | 0% |
| 2 | Control | 9 | 0 | 0% |
| 3 | Propane | 9 | 2 | 22% |
| 4 | Propane | 9 | 2 | 22% |
| 5 | Heater | 9 | 3 | 33% |
| 6 | Control | 9 | 2 | 22% |
| 7 | Heater | 9 | 2 | 22% |
| 8 | Heater | 9 | 1 | 11% |
| 9 | Control | 9 | 1 | 11% |
| 10 | Propane | 9 | 2 | 22% |
| 11 | Heater | 9 | 1 | 11% |
| 12 | Propane | 9 | 6 | 67% |
| 13 | Control | 9 | 4 | 44% |
| 14 | Control | 9 | 4 | 44% |
| 15 | Heater | 2 | 1 | 50% |

Table 2

Emergence by Plot

| | Emerged | Not Emerged |
|---|---|---|
| **Propane** | 12 | 33 |
| **Heater** | 8 | 30 |
| **Control** | 11 | 34 |
| **$X^2$ = 0.355724 d.f. = 2 p-value = 0.8371** | | |

Table 3

Contingency Analysis of Emergence by Treatment

It is not surprising that thermal treatment had no impact on emergence, since temperature logger data showed low heat increase and a low penetration of heat into the soil for both thermal treatments (see Table 4). The highest temperature reached was 86.0° F in the propane treatment at 2 cm deep. Other species of Leafcutter bee are known to tolerate temperatures up to 117.5° F with no increase in mortality (Barthell et al. 2002). While the North Coast stays relatively cool year-round, 86.0° F is not much higher than average ambient temperatures during the summer. Also, the short duration of this heat increase (~two minutes) seems unlikely to be long enough to cause harm to ground-nesting bees. The average temperatures seen in the propane treatment and the radiant heater treatment were very similar, though overall the propane treatment showed slightly greater heat increases than the radiant heater treatment. This is great news for land managers who are working to restore coastal dunes. They may continue to use their most efficient and effective method of exotic annual grass removal, the propane torch, with no negative effect on the nesting habitat of native pollinators. It is important for managers to consider the effect of invasive plant management on native pollinators, which are essential for restoring and maintaining a functioning ecosystem.

| PROPANE | 2 cm | 5 cm | 8 cm | Overall |
|---|---|---|---|---|
| Average | 78.6 | 76.5 | 73.7 | 76.4 |
| Standard Deviation | 4.9 | 2.9 | 2.3 | 4.1 |
| Maximum | 86.0 | 80.8 | 77.5 | 86.0 |
| Minimum | 73.2 | 73.2 | 71.4 | 71.4 |
| Range | 12.8 | 7.6 | 6.1 | 14.6 |
| RADIANT HEATER | | | | |
| Average | 78.6 | 76.3 | 73.4 | 76.2 |
| Standard Deviation | 4.0 | 2.4 | 0.7 | 3.5 |
| Maximum | 84.2 | 79.3 | 75.2 | 84.2 |
| Minimum | 74.5 | 73.9 | 72.9 | 72.9 |
| Range | 9.7 | 5.4 | 2.3 | 11.3 |

Table 4

Temperature Penetration Summary Statistics

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# DPR Laws and Regulations

## Herbicide Registration, Reregistration and Use Tracking, Tools to Help Make Herbicide Use Safe and Effective

*Denise Webster, California Environmental Protection Agency, Department of Pesticide Regulation, Pesticide Registration Branch, Sacramento, CA, dwebster@cdpr.ca.gov*

Pesticides play a unique role in environmental protection. Contradicting the usual preventive approach, pesticides are toxic by design and deliberately released into nature. This paradox is explained by the fact that, when used properly, both natural and synthetic pesticides protect people and their environment from pests – animal, plant or microbial – that threaten human health and the balance of nature. Indeed, nature created the first chemical pesticides, produced by some plants and animals to repel their natural enemies.

DPR continually reevaluates the health and environmental impacts of the pesticides it regulates, stressing risk reduction and, whenever possible, encouraging less use of pesticides in favor of more natural pest controls. Reevaluation is a tool DPR uses to find out whether specific pesticides are harming human health or the environment.

California's pesticide use reporting program is internationally recognized as the most comprehensive of its kind. DPR annually collects more than 2.5 million records of chemical applications. Reports include the amount and name of pesticide applied, date and location of the application, and crop, if the application was agricultural.

Over time, people observed, adapted, and improved on natural pest management. Like most human endeavors, the beneficial use of pesticides depends on information and sound judgment. Scientific knowledge of pesticides continually evolves and improves. California's approach is based on a strong scientific foundation and has built the most comprehensive pesticide regulation program in the nation. Our task is to ensure that pesticides are used safely. Our standards are uncompromising, as is our commitment to protect people and the environment.

## Mock DPR Use Monitoring Inspection: Application Do's and Don't's

*Chris Christofferson, John Knapp, Bob Case and Navid Khan*

DPR form PR-ENF-104 was used as a template to perform a mock application inspection. A county deputy agricultural commissioner will perform an inspection on two applicators that are involved in an herbicide application. The inspection featured experienced applicator Johnny Sprayright and Zed, a novice applicator. The right and wrong way to perform an application was presented with an emphasis on the laws and regulations of pesticide use covered by the form. Both the inspector and the experienced applicator tutored Zed to ensure his application will be safe and legal.

Main points (many of these are regulations, some are BMPs)

- Ensure the application site is identified properly
- Check for people, livestock, environmental conditions, site conditions prior to beginning applications
- Pesticide label need to be present on application site
- Gloves must be of approved type – usually nitrile rubber. Usually no leather, cotton or lined gloves
- Applicator must be trained and training records kept at office and available for inspection

- Protective eyewear needs to have brow and temple protection
- Service containers need to be labeled with the identity of the pesticide in the container; the name and address of the person or firm responsible for the container; and the signal word (caution, warning, danger) of the original product.
- Small spills can be spread or sprayed on site where finished product would be allowed
- Don't use food containers for holding or mixing pesticide
- Use secondary container to hold pesticide and measuring container
- Don't transport pesticides in same compartment with people
- Good practice to load application equipment partially with water, add pesticide, then add remaining water
- Good practice to avoid loading pesticide from the side of the equipment that will touch body
- Good practice to never raise pesticide equipment or spray nozzles above eye level
- Good practice for applicator to not walk through area being sprayed with pesticide. Either spray to side or spray while walking backwards, but being mindful of direction of travel
- A copy of the written recommendation and a copy of the use permit is required when a pest control business is applying a pesticide that requires a use permit (restricted pesticide).
- Handler decontamination for workers: Employers shall assure that sufficient water, soap, and single use towels for routine washing of hands and face and for emergency eye flushing and washing of the entire body are available as follows:
    - One clean change of coveralls shall be available at each decontamination site
    - A decon site for production ag uses shall be at mix/load site and not more than ¼ mile from other handlers
    - 1 pint of emergency eye flushing shall be immediately available for production ag uses if the label requires protective eyewear
    - A decon site for other than production ag shall be within 100 feet of the mix load site when handling danger or warning pesticides
- Good practice to not chew gum or smoke while applying or mixing pesticides
- New Respirator Protection Program (these are only some of the requirements)
    - Summarized in Publication # HS 1513 Generic Guidelines for Development of a Respiratory Protection Program in Accordance with Department of Pesticide Regulation Requirements
    - More information is available at www.cdpr.ca.gov/docs/whs/ind_hygiene_resp_prot.htm
    - When respirator use is required by the pesticide label, regulation, or permit conditions, companies must develop a written respiratory protection program with work-site specific procedures for respirator selection, medical clearance, fit-testing, inspection, maintenance and use, program evaluation, and provide for the purchase, storage, and training on the use of respirators
    - Each employee required to wear a respirator must submit a specific questionnaire to or submit to an examination by a licensed health care professional to be cleared to use a respirator

## Planning the Perfect Application: Making Sure Your Application is Politically Correct, Ecologically Correct and Legal

*Panel discussion: Bob Case, Navid Khan, Steve Schoenig, Erik Grijalva, Rich Marovich*

Stream alteration permits, endangered species regulations, NPDES permits, volunteer training requirements and other legal requirements can be confusing and difficult to negotiate for some land stewards, who are planning herbicide applications to manage invasive plants. In addition some non-governmental organizations have concerns about the use of herbicides by land stewards, professional applicators and volunteers. This session will make use of agency and organization experts to help plan the perfect application. In addition to the required permits and regulations that must be addressed, pre-application public relations and basic public related environmental concerns will be addressed.

- P.R.E.S.C.R.I.B.E. = Pesticide Regulation's Endangered Species Custom Realtime Internet Bulletin Engine
  - At http://www.cdpr.ca.gov/docs/endspec/prescint.htm
  - help pesticide applicators find out if they have any endangered species in the vicinity of their application site
  - and the advisory use limitations applicable to the pesticide product(s) they intend to use
- Agricultural commissioners permit the use of pesticides
  - Operator identification numbers required for production agricultural uses of pesticides and certain non-production uses
  - Restricted Use Permits required to use restricted pesticides
  - OID and permits require 100% pesticide use reporting
- CEQA impacts the use of pesticides
  - May need more than just a no impact designation to appease the public
  - Water is a sensitive site
  - Ensure the public is on board with your project
  - No surprises is a good strategy
  - The California Native Plant Society can help with endangered or sensitive species identification and or training
  - Species identification both target and non-target are critical to a perfect application
- BIOS database
  - Biogeographic Information and Observation System
  - At http://bios.dfg.ca.gov/
  - A system that enables the visualization of the spatial distribution of biological data generated by the Department of Fish and Game
  - $300 initial subscription $200 to resubscribe annually
  - Endangered species habitat locations described in ArcIMS

## Himalayan Blackberry *(Rubus discolor)* Removal and Wildlife Response

*Michael Rogner River Partners, Chico, CA, mrogner@riverpartners.org*

### Abstract

In February 2007, River Partners entered into an agreement with the City of Redding to restore 76 acres bordering Turtle Bay Exploration Park. The restoration is atypical in that there is already in place a mature overstory (50+ years) composed primarily of Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*) and Gooding's willow (*Salix gooddingii*). The primary focus is to remove and replace the invasive under- and mid- story, including 46 acres of Himalayan blackberry (*Rubus discolor*). A four-pronged approach to blackberry removal was developed to accommodate several concerns, including a neighboring pair of bald eagles, heavy public use and variable topography remaining from the site's previous use as a gravel mine for the construction of Shasta Dam. A herd of 1000 goats was used to defoliate the plants and improve visibility and safety for heavy equipment operators. The remaining canes were masticated using a Franklin Environmental Brush Cutter. Following this, re-sprouts were sprayed with Garlon©. After six months of chemical control the site was replanted with 4,900 native plants and until February 2010 the invasive blackberry sprouts will continue to be monitored and chemically treated, while the native plants will be irrigated for rapid growth to displace unwanted weed species. Additionally, 26,136 *Carex barbarae* plugs and 10-15 acres of mugwort (*Artemisia douglasiana*) will be planted in winter 2009. Avian data was collected in 2007 and 2008 using variable circular plot point count surveys, as bird metrics are being used to help evaluate the project.

### Introduction

Many riparian bird species use Himalayan blackberry for multiple purposes including nest substrate, cover from predators and as a food source. A study on Clear Creek, a Sacramento River tributary near the project area, found that yellow-breasted chats (*Icteria virens*) (a state species of special concern) construct their nests nearly exclusively within blackberry (Burnett and Harley 2003). One goal for this project is to remove the invasive Himalayan blackberry and replace it with a complex native understory which provides equal or better habitat for the riparian bird community. In order to measure the value of restored habitat, long-term monitoring is essential.

### Methods

The Turtle Bay Bird Sanctuary is a 76-acre parcel owned by the City of Redding. Approximately 46 acres of this property was infested with Himalayan blackberry, though there was in place a mostly native canopy composed of Fremont cottonwood, valley oak, and Gooding's willow (Rogner 2007).

A four-step approach is being used to accomplish the long-term goal of Himalayan blackberry removal. A herd of 1000 goats was used to defoliate the plants and improve visibility and safety for heavy equipment operators. The remaining canes were masticated using a Franklin Environmental Brush Cutter. Following this, re-sprouts were sprayed with Garlon©. After six months of chemical control the site was replanted with 4,900 native plants and until February 2010 the invasive blackberry sprouts will continue to be monitored and chemically treated, while the native plants will be irrigated for rapid growth to displace unwanted weed species. Additionally, 26,136 *Carex barbarae* plugs will be planted in winter 2009, as well as 10-15 acres of mugwort plugs.

Bird data is being collected using variable circular plot point count surveys. Plant surveys include a complete annual census to determine survival, and permanent plot sampling to monitor growth and cover of native plants.

## Results and Discussion

Significant federal, state and private resources are being put to use restoring and enhancing riparian habitat in California. Identifying areas of high priority for restoration however is usually done on a project by project basis, which is a practical approach driven by funding sources. Because of funding restrictions, this process usually leads to projects without long-term monitoring, which is critical to understanding how habitat restoration projects are affecting state wildlife populations. Long-term data are vital to determining the difference between true changes in metrics and natural fluctuations, and datasets should include both restoration and reference sites (RHJV 2004).

The restoration of the Turtle Bay Bird Sanctuary is on a parcel of land open to the public and thus access is available for long-term monitoring. It is also a key site for monitoring as the type of restoration is atypical for large-scale habitat restoration in that it involves understory enhancement in an area that already hosts a healthy canopy of native trees. The primary non-native plant being removed is Himalayan blackberry which does offer significant habitat for native riparian songbirds. In fact, a study of yellow-breasted chats on nearby Clear Creek in Shasta County found that this species nests nearly exclusively in blackberry (both native and non-native), and that the young are routinely seen foraging in blackberry after fledging. Additionally, Himalayan blackberry produces an enormous amount of food and does so at a time when young birds are fledging from nests and are still developing the skills necessary to forage on their own. A stand of Himalayan blackberry provides a quick and easily exploitable food source (Young and Burnett 2007).

Monitoring at the Turtle Bay Bird Sanctuary includes both bird and plant datasets. The goal of the project is to remove the non-native species and replace them with a more complex suite of native plants that offer habitat structure and foraging resources that are superior to those being supplied by Himalayan blackberry. The project is in its early stages and thus far two years of monitoring data are available – one prior to any work being done in the area and one collected just after the planting phase. Continuing data collection in the upcoming years (decades) is critical to understanding the habitat associations and changes which are beginning to take shape.

Two years of data show that the removal of Himalayan blackberry is currently over 99% effective.  While concerns remain about re-colonization of this species following the end of the

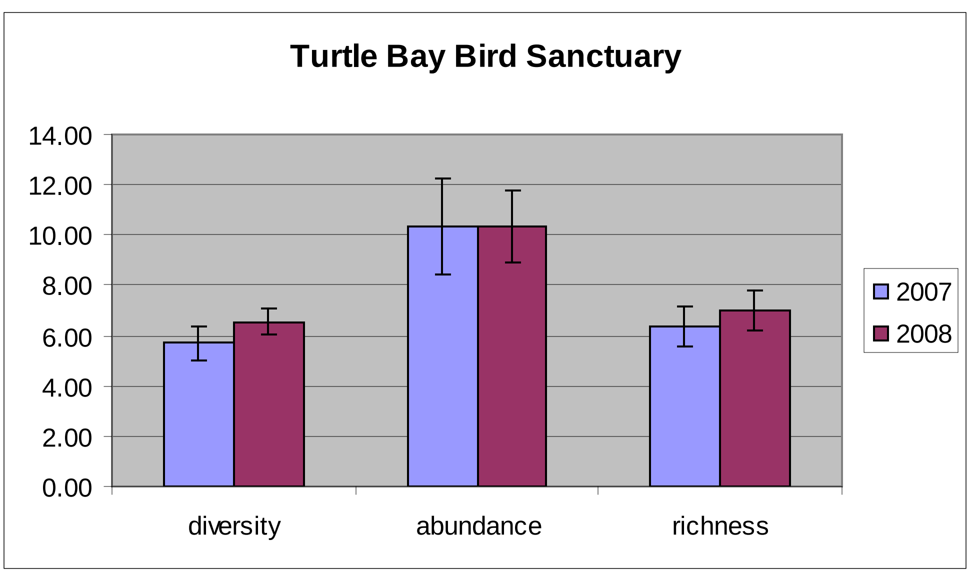


Figure 1

Avian Metrics at Turtle Bay Bird Sanctuary maintenance period it is critical to "walk away" from the project with near total eradication in order to give the newly planted native species a chance to out-compete future invasions. Bird monitoring shows a slight increase in diversity and species richness in the year following blackberry removal. Future monitoring and comparisons with nearby sites will help determine how annual variation and other factors are affecting the data.

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# Exotic Control and Habitat Enhancement in Southern Californian Native Grasslands at an Audubon California Preserve


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## Abstract


After one to two years of non-chemical control of the grassland invader, artichoke thistle (*Cynara cardunculus*) at Audubon's 4000-acre Starr Ranch, seasonal field crews initiated native grassland enhancement. Because of seed collection constraints and low success of active restoration, the focus is currently on maintenance and enhancement of about 300 acres of needlegrass (*Nassella pulchra*) grassland. Ongoing mapping and non-chemical control continue long-term for Italian thistle (*Carduus pycnocephalus*), bull thistle (*Cirsium vulgare*), tocolate (*Centaurea melitensis*) and other exotic species. From 1999-2004, we monitored native grassland stands for native bunchgrass density and cover and richness of all species. After a record-breaking drought in 2001-02, our data indicated a dramatic decline in bunchgrass density. So, in spring 2003 we began the first of our multi-site, multi-year experiments and trials on brush cutting (or mowing) to enhance the existing native grassland. Results from our first smaller scale (2 x 2 m plots) experiment indicated that a second, early season brush cut (at about 6") may have negative effects on needlegrass density and cover. The next season we scaled up (5 x 20 m plots) and reduced mowing frequency. Treatments are ongoing and each season we put in a new mowing experiment, modified from what we've learned, to test treatments in a different site and a different rainfall season. In spring 2007 we initiated bird monitoring to assess habitat quality in 220 acres (12 stands) of needlegrass grassland. Results indicated that one rare species, Grasshopper Sparrow, is present in all 12 stands.


## Introduction

California's native grasslands have undergone a greater percentage loss than any other vegetation type in the state. Over 98% of California grasslands are dominated by exotic plant species (Noss *et al*. 1995). Audubon's 4000-acre Starr Ranch protects about 700 acres of native and degraded grasslands. Our grassland enhancement project seeks to eventually control exotics and enhance native grasses in 450 of those acres. Currently we're doing research, exotic control, and enhancement in about 300 acres of needlegrass grassland at Starr Ranch.

## Methods

Starr Ranch is a 4000-acre Audubon preserve in southeast Orange County, California. The Ranch protects a mosaic of lower elevation vegetation types, including coastal sage scrub, chaparral, oak and riparian woodlands, and grassland. Experimental work on grassland enhancement was preceded by long term monitoring data in n = 50 one $m^2$ quadrats in each of six pristine (i.e. > 30" cover of the dominant bunchgrass, *Nassella pulchra*) Starr Ranch native grasslands that indicated a decline of *N. pulchra*, after a season of record-breaking drought. Subsequent low success of both active (seeding) and passive (exotic control coupled with monitoring of native bunchgrass populations) needlegrass grassland enhancement motivated initiation of a series of experiments to investigate the effects of brush cutting or mowing to enhance the bunchgrass. In different sites and different years, experiments have tested brush cutting or mowing once or twice early in the season at 4 – 6" grass height. Plot size and experimental design vary, depending on site conditions (patch size, bunchgrass cover).

## Results and Discussion

After clearing most of the exotic cover from a disturbed area of a needlegrass grassland stand and seeding *N. pulchra* at different rates, we measured low success of these active enhancement efforts (mean cover *N. pulchra* 5.8 ± 21 % after four seasons). These results led us to continue to monitor in six of our most pristine native grassland stands as we developed a strategy for enhancement of existing stands. Our observations of a sharp decline of *N. pulchra* density and cover after a record-breaking drought season (Figure 1), stimulated initiation of our first experiment on brush cutting to enhance the bunchgrasses. We chose cutting as a management strategy because researchers have indicated that not only have native grasslands been recognized as disturbance-dependent systems but also that managers are mowing without understanding mowing frequencies or intensities (Hayes and Holl 2003).

Mowing treatments at Starr Ranch are only applied during years of > 5" cumulative precipitation for the season by the end of February and are terminated if significant decline results. Results of an experiment in 2 x 2 m plots showed a significantly negative effect ($p = 0.0006$) of a second early season brush cut. Thus, the next season we scaled up to larger (5 x 10 m) plots in an experiment in the same stand that tested just one early season cut. No significant effects from one early season cut have been detected over three seasons (during which conditions were optimum for brush cutting, by our arbitrary standards, during only one of the three seasons). We've added several other experiments in different grassland sites to test the effects of mowing and have not yet detected significant effects. However, because of the highly variably precipitation in our semiarid region, experiments will be continued long-term.

Mapping and non-chemical control of exotics is an ongoing process that accompanies efforts to stimulate *N. pulchra*. Because of time and fund-

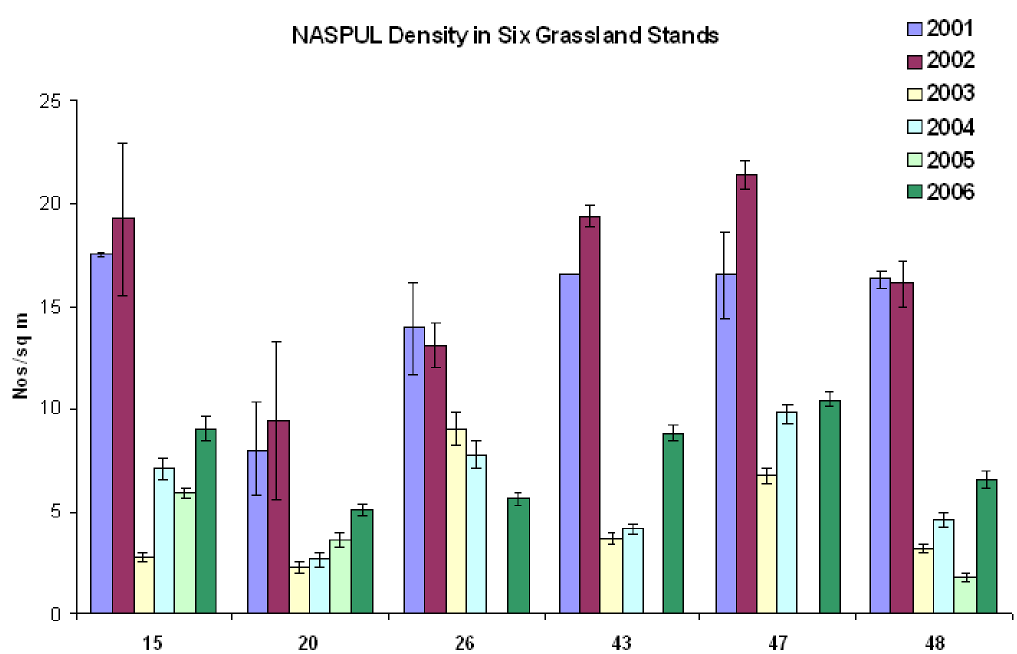

Figure 1

ing constraints, our crews do literature reviews on new exotics as we detect them and only do experimental tests of alternate treatments if there is no clear control method available. In 2007, our field crews began spring qualitative surveys of two grassland bird species who serve as indicators of habitat quality. One of the species, Grasshopper Sparrow, is listed among the ten common birds in decline in the continental U.S. (Butcher 2007). Grasshopper Sparrows were present in all 12 stands (220 acres) surveyed in 2007 and in 9 of 12 stands in 2008.

Our experiments and monitoring are long-term and ongoing. Though we deal with a continual tradeoff between power and rigor (required of good experimental design) and efficiency (the need to get the work done), we will continue to take a research-based, non-chemical approach to exotic control and native grassland enhancement. We estimate annual costs of exotic control, currently the predominant grassland enhancement technique in about 286 acres, during the last El Nino season (34" ppt in 2004-05) to be about $65/acre.

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## Perennial Pepperweed (*Lepidium latifolium*) Control in Tidal Marsh of San Pablo Bay


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### Abstract


The San Pablo Bay National Wildlife Refuge began a program in 2005 to control invasive pepperweed (*Lepidium latifolium*) in tidal marsh of San Pablo Bay. A field census of pepperweed within 1,700 acres of tidal marsh was completed in 2005. The project area extended from the mouth of the Petaluma River east to Sonoma Creek. Results showed pepperweed was commonly associated with the levee-marsh interface (45%), channel edges (18%), and along the bay edge (31%), areas influenced by a natural or man-made disturbance. Over 60 gross acres and 30 net acres were infested with pepperweed within the project area. The mapping data was combined with the best available information on pepperweed ecology and control methods to develop a control plan for San Pablo Bay. Chemical control using imazapyr (Habitat©) was identified as the preferred method. Control efforts were initiated in 2007 and continued in 2008. We conducted an experiment to test pepperweed control, the efficacy of imazapyr and an imazapyr-glyphosate cocktail and to evaluate effects of these treatments on native plants. First year post-treatment results showed a significant ($p<0.001$) reduction in pepperweed when imazapyr or a cocktail of imazapyr plus glyphosate was applied relative to removal of seed heads (controls). Cover of pickleweed (*Sarcocornia pacifica*) was significantly lower in the imazapyr-glyphosate plots relative to controls. These results suggest the use of imazapyr may be an effective tool for controlling this species in tidal marsh of San Pablo Bay while conserving cover of native plants.


### Introduction

The San Pablo Bay National Wildlife Refuge contains some of the largest remaining stands of tidal marsh in the San Francisco Estuary and a unique array of wildlife and plants. The Refuge also provides habitat for endangered and threatened species and thousands of birds that migrate along the Pacific Flyway. Invasive plants are one of the leading threats to tidal marsh of San Pablo Bay. Species of concern at this time are perennial pepperweed (*Lepidium latifolium*) and invasive cordgrass species. The focus here is pepperweed.

Since initial invasion of the San Francisco Bay Area (1950s), pepperweed abundance has increased exponentially (Grossinger *et al*. 1998, May 1995, Trumbo 1994). The Refuge began a program in 2005 to control pepperweed in tidal marshlands of San Pablo Bay. The objectives of the program are to 1) determine pepperweed abundance and distribution, 2) develop a control plan, 3) study efficacy of control methods and 4) significantly reduce the cover of pepperweed. Results presented here focus on objectives 1 and 3.

## Methods

The project area encompasses tidal marsh along the northern border of San Pablo Bay, from Sonoma Creek to the Petaluma River. Dominant native plants include pickleweed (*Sarcocornia pacifica*), alkali heath (*Frankenia salina*), gumplant (*Grindelia stricta*), saltgrass (*Distichlis spicata*), Pacific cordgrass (*Spartina foliosa*) and jaumea (*Jaumea carnosa*). A complete census of pepperweed was conducted in 2005-2006 using global positioning systems (GPS), ArcPad© software, and the Weed Information Management System (WIMS). Attributes of individual pepperweed patches included date, observer, percent cover class, phenology, and micro-environment (e.g., channel edge). Patch size was generated from GPS data. Spatial data were examined to determine gross and infested acres of pepperweed by cover class and relationships to the environment. Imazapyr was applied to pepperweed patches during the late bud to flower stage (May-June) using backpack sprayers in 2007. The experimental area was excluded from the larger treatment area.

We established an experiment within a portion (50 acres) of the larger project area to test the relative efficacy of the herbicides Habitat® (active ingredient imazapyr) (I) and an imazapyr/glyphosate cocktail (IGC) relative to inflorescence removal (controls). Hawth's Analysis Tools (Beyer 2004) were used to select twelve random points, with at least ten meters of distance between each point, within three environment types (channel, bay edge, levee). Random sorting was used to allocate four replicates each of three treatment methods within each of the three environment types for a total of 36 points. We established 1m$^2$ monitoring plots at each point. Pepperweed within plots and in a surrounding buffer of 1.5 meters was treated using the randomly assigned treatments (I, IGC, controls). Pepperweed stem counts, rosette counts, and percent cover of native species were conducted pre- and post treatment within the 1m$^2$ plots during late spring 2007. We calculated percent change in pepperweed (LELA) abundance for each plot as (-100)* ((LELA total 08-LELA total 07)/100). LELA total included stems and rosettes. Positive values represented a reduction in pepperweed. We tested the null hypothesis of 1) no difference in pepperweed abundance between control and treated plots and 2) no difference in cover of native plant species between control and treated plots using an analysis of variance (ANOVA). A least squares fit test was used to test for effects of environment and treatment on percent change in pepperweed abundance.

## Results and Discussion

More than 1,700 acres of tidal marsh were surveyed, resulting in 67.91 gross acres and 30.32 infested acres of pepperweed. Over 40% of the patches mapped contained pepperweed in the 51-100% cover class (Table 1). Pepperweed was most commonly encountered along the levee-

| Marsh Feature | Gross Acres | % of Total |
|---|---|---|
| Marsh plain | 3.44 | 5.06 |
| Sloughs and channels | 12.54 | 18.47 |
| Bay edge | 21.23 | 31.26 |
| Levee/berm | 30.70 | 45.21 |
| **Total** | **67.91** | |

Table 1

Pepperweed distribution and abundance in tidal marsh of San Pablo Bay tidal marsh interface (45%) and along the bay edge (31%). The lowest level of infestation was found in the marsh plain.

Chemical treatment of the project area (imazapyr only) and our experimental plots occurred in late May 2007. This coincided with the late bud to flower stage for the majority of occurrences. Imazapyr alone reduced total pepperweed abundance by 76-100% one year post treatment (N = 9 plots), while imazapyr plus glyphosate reduced stems by 86-100% (N = 11 plots). Control plot abundance ranged from an increase of 308% to a decrease of 67% (N = 16). ANOVA indicated that plots treated with either treatment type had significantly greater efficacy in stem reduction than untreated control plots ($p<0.0001$) (Figure 1). The comparisons of means (Tukey's HSD test) showed the two chemical treatment types are statistically equivalent in their ability to control pepperweed in the first year post-treatment. Micro-environment (levee, channel, or bay edge) appeared to have no effect on the percent change in pepperweed abundance following treatment ($p = 0.13$). A significant difference in pickleweed cover between the imazapyr plus glyphosate treatment and controls was observed ($p = 0.02$).

Our data show that pepperweed is strongly associated with areas of tidal disturbance (e.g., tidal deposition areas). Fewer patches were observed in undisturbed marsh plain, suggesting these environments have lower potential for invasion although patches of pepperweed do expand into these areas. Most surprising was the relative abundance of pepperweed along the bay edge. A natural berm occurs along much of the tidal marsh edge of northern San Pablo Bay. The berm runs parallel to the transition between low marsh and high marsh, where pickleweed meets Pacific cordgrass. Like the tidal-marsh levee interface and channel edge environments, tidal deposition of organic material and disturbance takes place along the bay edge berm on a regular basis, creating a disturbance regime where pepperweed can take hold.

One of the primary objectives of our project was to evaluate methods that may effectively control pepperweed. Based on current knowledge and the limitations of a tidal marsh environment, chemical application of herbicides is currently our best option. Our first year results show that imazapyr (I) and the imazapyr plus glyphosate cocktail (IGC) are effective in reducing pepperweed growth. The IGC treatment appeared slight more effective than imazapyr but this was not a significant finding. Pickleweed cover decreased in the chemically treated plots but we only found a significant difference in pickleweed cover between controls and the IGC treatment. Cover of alkali heath was not significantly different between chemically treated plots and controls.

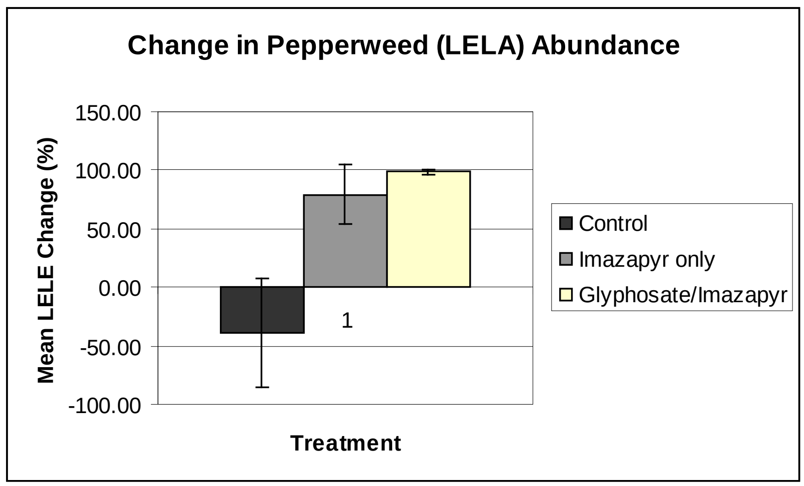


Figure 1

Mean change in pepperweed abundance between controls and chemically treated plots (2007)

We were unable to analyze effects to all native species due to the low number of plots in which native species occurred. For example, saltgrass (*Distichlis spicata*) occurred in only one plot that was treated with ICG. Here, saltgrass mortality was 100% and did not recover one-year post treatment. Plots were treated again during late spring/early summer 2008. Results from the two-year study will be used to adapt current pepperweed control program for tidal marsh in San Pablo Bay.

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# Looking to the Future: Research and Prediction

## Assessing Research Priorities for Invasive Plants in California

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### Abstract

California has over one thousand introduced plant species, many of which are invasive in wildlands. In 2006, the California Invasive Plant Council rated the most invasive plants in the "California Invasive Plant Inventory". During the research compilation process for the list it became evident that information was lacking on many species. In addition, the limited availability of funding for management and control programs makes it important to know where current research gaps are and where future research should be focused. The Research Needs Assessment project was formed in 2005 at UC Davis. The project summarizes existing research pertaining to invasive plants in California through literature review and interviews with researchers and identifies high-priority needs for future research. It addresses ten topic areas including biology, ecological impacts, distribution and modeling, human caused impacts (i.e. climate change, nitrogen deposition), economics, social issues, and policy. Our talk presented research needs gleaned from interviews with 45 experts in invasive plant research and management. A draft of our findings is available, as well as a directory of invasive plant researchers in California. We encourage input and a final document will be available by the end of 2008 on the Cal-IPC website.

### Introduction

The Research Needs Assessment project began in 2005 as a meeting of experts at UC Davis with the goal of bringing together researchers and land managers to discuss major research gaps that hinder efforts to manage invasive plants. The project summarizes existing research pertaining to invasive plants in California through literature review and interviews with researchers and managers, and identifies high-priority areas for future research. Through this effort we seek to:

1) Facilitate connections between disciplines by increasing awareness of the range of ongoing research on invasive plants;
2) Create a forum for assessing high-priority research needs; and
3) Guide future research (especially graduate student projects) toward these high-priority needs.

The need for effective strategies in invasive species research is outlined well in Byers *et al*. (2002). In brief, the authors emphasize the need for prioritization of invasive species for management purposes so conservation managers can decide where to focus control efforts. California's Noxious and Invasive Weed Action Plan (2005) also identifies the need for this type of research needs analysis.

### Methods

The information from the original 2005 meeting served as the starting point for the project and from there a list of experts in each area was developed by a committee chaired by Cal-IPC. The experts were contacted by telephone and e-mail to provide comments in their areas of expertise and their contributions were summarized in the project report.

### Results and Discussion

Overall, synthesis of research in biology and ecology, ecological impacts, control and management, restoration and social issues related to invasive plant management was commonly identified as necessary. Academic research results need to be made available to the larger management community in order to keep the lines of communication open in both directions. Results from land managers also need to be published in newsletters or other web-accessible locations so they are available to the larger community. Active partnerships are needed between the invasive plant community and economists and social scientists. Finally, funding and active mentoring is needed to direct graduate students toward these research questions.

Some critical research needs identified during interviews were:

### Biology and Ecology

- Initiate studies of seed biology and seedbank dynamics to aid long-term eradication projects
- Encourage below-ground biological research as a key to understanding above-ground dynamics

### Ecological Impacts

- Document the impacts of invasive plants on natural communities at different scales, especially the effects of "ecosystem transformers"
- Study interactions of wildlife and invasive plants; are they positive or negative?
- Determine threshold densities of invasive plants which cause minimal ecological impacts and research how to manage systems to retain the invasive plants at that level

### Distribution, Biogeography and Range Modeling

- Produce state-wide distribution maps for invasive plants
- Develop easy ways for land managers to use modeling to predict spread of invasive plants
- Studies on time to reproduction and rate of spread in different habitats
- Identify habitats resistant to invasive plant establishment and determine factors that make them resistant

### Risk Assessment

- Implement more effective pre-border screening and post-border prioritization methods
- Improve techniques for Early Detection and Rapid Response
- Offer alternative plants to replace the invasive ones currently offered for sale

### Human Pathways and Prevention

- Plan for potential changes to invasive plant distribution and abundance under different climate change scenarios

### Control and Management Methods

- Analyze ecosystem impacts of control methods
- Study using management techniques to substitute for ecological processes. For example, can grazing or mowing replace fire?
- Monitor to determine what the ecosystem impacts are of biological control agents

### Restoration

- Develop methods to increase the effectiveness of active and passive restoration projects and decrease invasive plant establishment

### Economic Impacts

- Calculate the real economic costs and impacts of invasive plants

### Social Issues

- Develop effective communication and messages to convey the need for invasive plant management

### Policy and Laws

- Integrate scientific research findings into development of effective policy at the state and national levels

The research needs for invasive plants in California presented here are meant to reflect the opinions and expertise of those interviewed as well as those of the larger community. Consequently, we are soliciting additional input from members of the community and will post document updates and additions on the Cal-IPC website. For additional information or to contribute please contact Cal-IPC. The final assessment will be posted at www.cal-ipc.org.

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# Follow the Weeds: Assessing the Risk of Future Spread

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*(This article is adapted from the Cal-IPC News, Fall 2008.)*

## Abstract

Risk assessment – the evaluation of current and potential future impacts – is a critical component of invasive plant management and policy and is essential to implementation of state and federal plans. In an era of reduced budgets, land managers need to know where to focus their work to produce the most effective ecosystem restoration. Predictive models can help early detection by showing where invasive plants may spread and predicting the effects of changing conditions under global climate change. We determined the current range and predicted spread of 36 invasive plants. We surveyed Weed Management Areas for data on current extent and population status (stable, increasing, decreasing due to control). To predict future spread, we researched native and introduced ranges of these plants globally and applied information through the climate-based modeling software Climex. Comparing climatic characteristics from each plant's existing range with those from California regions enabled us to extrapolate the potential success of that plant here. We then applied a climate-change scenario to determine how climate change will affect predicted range. Results show that some of these species have the potential to greatly expand their ranges. Climate change will expand suitable habitat for some species while reducing it for others.

## Introduction

Those who work to control invasive plants and restore habitats must balance their plans between the present and the future. Most of the work that happens in both research and management addresses the present, or at least the next couple of field seasons. For the past two years, Cal-IPC worked on a project to improve information on where invasive plants occur now while assessing the risk of them spreading in the future. What weeds do your neighbors have? What new weeds are most likely to thrive in your county? What will happen as global climate change progresses? Risk assessment predicts which plants (or other organisms) could become problems, divided into two types. "Pre-border" assessments study organisms not yet present in a particular region while "post-border" assessments predict the spread of species already present.

Cal-IPC's risk assessment project addresses invasive plants already here and those that could invade, with several specific objectives. First, determine the current range in California of all species on the Cal-IPC Inventory. Second, predict where a subset of those species could spread, using climate-modeling software. Third, identify areas in California vulnerable to expansion of the 36 modeled species. Finally, identify plants that are invasive in other Mediterranean-type regions and might become invasive here.

## Methods

To determine the current distribution of invasive plants, we surveyed Weed Management Areas for information on invasive plants in their counties, including rough estimates of total area infested and whether populations are increasing, declining due to control efforts, or stable. We began with 36 species in the summer of 2007 and added the remaining species from the Cal-IPC Inventory (Cal-IPC 2006) in 2008.

We then used climate-modeling software to predict the areas of California with suitable habitat for 36 plants. These species were a representative sample from the Inventory, with a range of growth forms, habitat preferences, severity of impacts, and regions currently invaded. Climate modeling compares the climate of the native and invasive range of a species to the climate of California. The software (CLIMEX) uses temperature and soil moisture tolerances of each species to generate an "ecoclimatic index" that rates a plant's ability to survive. Online herbaria and flora databases gave us information on where plants grow worldwide. This method provides a rough estimate of where plants can grow but it is one of the few types of analysis that can be carried out without detailed experimental data. We compared the sum of ecoclimatic indices for all 36 species to those predicted with a 3°C increase in average annual temperature.

We combined WMA data on existing populations with predictions of areas with suitable climate to produce maps that areas not currently invaded by these species that appear to have very suitable climate for them. Our models are based solely on climate and do not consider other factors such as soil type, competition, or probability of a species being transported.

To identify plants that may become invasive in California in the future, we examined lists of weeds in other Mediterranean climate areas. Several studies have found that the single best predictor of whether a plant will become invasive in a particular place is its being invasive in another region with a similar climate. We determined which species already naturalized here and the earliest date of a specimen of each species recorded in a California herbarium, based on online databases. To narrow the list, we eliminate species that had been recorded before 1940 and was not yet invasive here. Others were eliminated from consideration because they are considered very minor weeds or the information was inadequate.

Ornamentals are a major pathway of introduction. We determined how many of these plants are ornamentals, either already available on the west coast or used in horticulture elsewhere. We assumed that plants listed in the Sunset Western Garden Book (Brenzel 2007) or the Plant Locator (Hill and Narizny 2004) are available to California gardeners.

## Results and Conclusions

Results increased the known distribution of a number of species while climate models showed some patterns in possible future distribution. Data from the first set of 36 plants provided more information on location than we had before and added to the data in the Inventory. Climate models revealed some patterns in predicting suitable habitat. Not surprisingly, species that grow in a few counties along the coast could fill in the remaining counties. The models also showed that many species that can survive in the San Francisco Bay Area could grow in the Sierra Foothills. Climate change models showed only a 2% increase in the total ecoclimatic index (EIS summed for all species), indicating that invasive plants will not automatically gain a large advantage simply due to warming temperatures. Analysis of the climate change data is ongoing; however, we have found a few clear winners and losers. Castor bean (*Ricinus communis*) and fountaingrass (*Pennisetum setaceum*) would nearly double their EIs. Half of the species listed as invasive in other Mediterranean regions are already naturalized in California according to the Jepson Manual (Hickman 1993) but are not listed as invasive by Cal-IPC.

We hope that these results will prove useful to land managers and policy makers. Our future plans (pending funding) include producing models on more species, perhaps focusing on High and Moderate Alert plants from the Inventory as those have strong impacts but are not yet widespread. We would also like to work with wildlife groups to examine how our predictions for invasive plants relate to identified important areas for wildlife, especially threatened or endangered species. Maps and lists of weeds from other Mediterranean areas are posted on the Cal-IPC website:

## Acknowledgments

Thank you to all the WMAs that volunteered data and expert opinion. Len Liu and Colleen Murphy provided GIS expertise. Jeremiah Mann collected survey results, Bertha McKinley looked up hundreds of plants in Sunset and Jepson.

Special thanks to S. Steinmaus for his meteorologial data and J. Hall, B. Leger, R. Klinger, M. Pitcairn, S. Schoenig and L. Wihbey for additional information and advice. The Exotic Pests and Diseases program of the UC Integrated Pest Management program provided funding.

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## A New Agenda for Managing Invasive Species in California Estuaries

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Although invasive species are widely acknowledged to be one of the primary threats to coastal estuaries, there is also broad agreement that substantial gaps persist at the intersection of science and policy that complicate the management of invasive species. We highlight some of the issues that have either facilitated or impeded the successful union of the science and management of introduced species including the underlying regulatory framework. We draw on recent examples of eradication attempts in coastal estuaries to underscore these points. In an effort to push forward a more constructive approach to bringing science and management more closely together, we suggest a research agenda that focuses on science that can really assist invasive species management and that incorporates the views and opinions of managers facing the daunting task of managing invasive species in coastal habitats. In addition to emphasizing issues such as early detection and rapid response, we also focus on population connectivity, the potential for rapid evolution, responses to climate change, and approaches to decision support that will help to guide the management of invasive species now and into the future.

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## Effects of Nitrogen Deposition on Vegetation-Type Conversion in Riversidean Sage Scrub

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### Abstract

Anthropogenic nitrogen deposition has been occurring in western Riverside County for the past half-century, and during the same time period there has been extensive vegetation-type conversion of Riversidean sage scrub to exotic annual grassland. Levels as high as 30 kg N/ha/yr occur as dry deposition from automobile emissions, with highest levels in urban northern regions, and decreasing along a gradient southward. Vegetation was sampled along a nitrogen deposition gradient and also in nitrogen-fertilized plots at a site with relatively lownitrogendeposition. Exotic grass cover was positively related to elevated soil nitrogen along the gradient, while native shrub and forb cover and richness were negatively related to soil nitrogen. Fertilization with 60 kg nitrogen $ha^{-1}$ $yr^{-1}$ caused an increase in biomass in exotic grass after two years, while decreases in native forb cover occurred after eleven years of fertilization. Shrub cover did not change significantly during this time period. Grass biomass of 0.5-1 T/ha in soils with elevated nitrogen may be a cause of more frequent fire, as has occurred in the Riverside area. The combination of increased grass fuel for fire and more frequent fires may drive the conversion of Riversidean sage scrub to annual grassland.

### Introduction

Vegetation-type conversion has been occurring due to exotic invasions in California for over two centuries, but in the last 50 years there has also been a rapid conversion of Riversidean sage scrub (RSS) to exotic annual grassland, especially *Bromus rubens*. Type conversion has been largely near urban areas of western Riverside County that are also subject to high levels of anthropogenic nitrogen deposition. Frequent fire may also be a cause of vegetation type conversion in areas receiving high nitrogen deposition. This research examined the effect of elevated nitrogenon exotic grass production as a fuel for fires.

N deposition may originate from automobile emissions as nitric acid, or from agriculture as ammonium (Fenn *et al*. 2003). In the Mediterranean-type climate of southern California, most is deposited in dry form as ionic and particulate nitrogen. Air pollution is greatest during the summer dry season, when nitrogen accumulates on soil surfaces until the fall/winter rains make it available for plant growth. Surface soil nitrogen-concentrations increased along an air pollution gradient from rural to urban western Riverside County (Padgett *et al*. 1999), suggesting a relationship between nitrogen deposition and soil nitrogen. There also appeared to be greater loss of RSS with increasing nitrogen along this gradient.

To test the relationship between nitrogen deposition and vegetation-type conversion, cover and richness of native and exotic vegetation were assessed in seven sites along the gradient with nitrogen deposition ranging from 8 to 20 kg nitrogen/ha/yr (Tonnesen *et al*. 2007). Because natural gradients may have multiple factors that vary together, a set of plots was fertilized with nitrogen over eleven years at the clean end of the air pollution gradient. This allowed observation of responses to nitrogen fertilizer under controlled conditions in a replicated, blocked design.

### Methods

Seven sites were selected in RSS vegetation on north-facing slopes along a north to south, 70 km nitrogendposition gradient from the Jurupa Hills (north of Riverside) to the Tucalota Hills (near

Temecula). All of the sites are on granitic parent material with sandy loam to sandy clay loam soils, and none of the sites had burned in at least ten years. The vegetation was sampled in spring, 2003 when native annuals were at their peak of flowering. At each site three 1-ha plots were selected with 20-100 m distance between plots. The shrubs were sampled with 250 m of line transect in each 1-ha plot. Understory vegetation cover and species richness was sampled in fifty, 25 X 25 cm quadrats in each 1-ha plot. Finally, species richness of each 1-ha plot was sampled during a walk-through to list each additional species that did not occur in the quadrats or transects.

Table 1

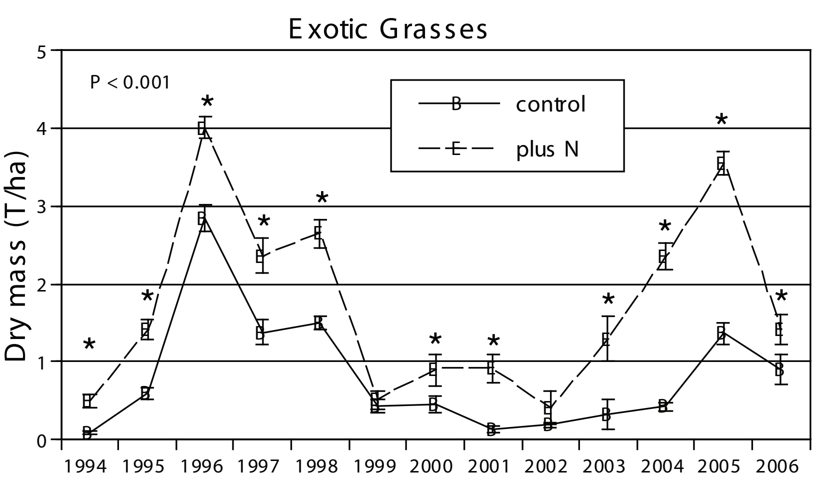
Percent cover and richness (per 3 ha) of plant groups along a 1N deposition gradient in western Riverside County. Sites are arranged from N to S along an urban to rural gradient. Soil N is extractable nitrate plus ammonium, N deposition is modeled wet plus dry deposition (Tonnesen et al. 2007).

| | Exotic grass | Native forb | Shrub | Native forb | soil N | N deposition |
|---|---|---|---|---|---|---|
| Site | % cover | | | #/3 ha | µg/g | kg N $ha^{-1}$ $yr^{-1}$ |
| Jurupa Hills | 63.5 | 4.0 | 2.2 | 16 | 37.7 | 19.6 |
| Box Springs | 69.2 | 18.5 | 2.4 | 31 | 32.6 | 14.7 |
| Botanic Garden | 36.0 | 25.4 | 0.2 | 20 | 28.9 | 13.4 |
| Lake Perris | 0.5 | 26.1 | 2.8 | 30 | 20.3 | 11.1 |
| Mott Reserve | 6.7 | 14.3 | 11.2 | 37 | 30.6 | 11.1 |
| Lopez Canyon | 11.1 | 19.6 | 19.3 | 67 | 9.6 | 9.0 |
| Tucalota Hills | 1.5 | 35.7 | 35.0 | 50 | 10.5 | 8.7 |

The nitrogen fertilization experiment was done at Lake Skinner on relatively level ground (~5% slope, S-facing) that was last burned in a November, 1993, wildfire.nitrogenfertilizer was applied in a block design with ten replicates in two rows of ten, 5 X 5 m plots with 1.5 m aisles between plots. Randomly selected plots in each block received 60 kg $ha^{-1}$ $yr^{-1}$ ofnitrogenas $NH_4NO_3$, double the highest amount of nitrogen deposition known from shrublands in the region. The nitrogen was added twice yearly, once at the beginning of the rainy season (typically December) and a second time during mid-growing season (February), between the 1993-94 and the 2003-04 growing seasons. Beginning 2005 fertilization was discontinued, but plant growth measurements were still done. The objective of ending fertilization was to determine the rate at which plant response returns to control when nitrogen inputs cease. Native and exotic herbs were measured annually in four, 25 X 50 cm permanent quadrats in each plot. For an estimate of herbaceous biomass, double sampling was done by clipping herbs outside the permanent plots. Shrub cover was measured in June or July each year in three, 4-m line transects within each 5 X 5 m plot (avoiding edges).

Figure 1

A) Biomass (T/ha) of exotic grasses and B) percent cover of native forbs during 11 years of annual fertilization with 60 kg N/ha, and 2 years post-fertilization (2005-06). P value is based on repeated measures ANOVA.

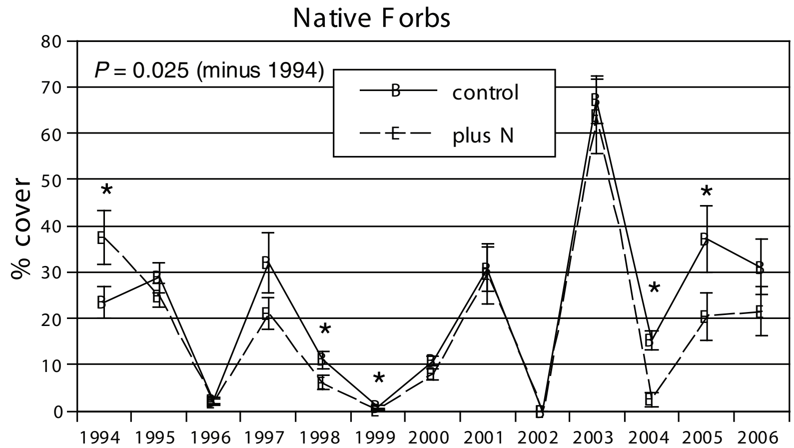



## Results and Discussion

The richness of native forbs decreased significantly ($P$=0.01) with increasing soil extractablenitrogenand increasingnitrogendeposition (Table 1). The opposite response was observed for exotic grasses, which increased significantly ($P$ = 0.001) in cover from 1 to 69 % with increasing extractablenitrogenandnitrogendeposition. There was no relationship between soilnitrogenand exotic grass richness, as there were only 3-6 exotic grass species per site. Exotic forbs also did not follow a pattern in richness across the soilnitrogengradient, and the relationship between exotic forb cover and soilnitrogenwas not significant (data not shown). Native shrubs had significantly reduced cover with elevated soil N but no significant change in richness.

Grass biomass increased with N fertilization during most years (Fig. 1a), but there were significant changes in cover of native forbs in only five of eleven years (Fig. 1b). In the first year, forb cover was greater in fertilized plots, but in other years their cover was decreased following fertilization. This may be caused by competitive interaction with the grasses that increased following fertilization. Exotic forbs had no significant response, and native shrubs had decreased cover in nitrogen-fertilized plots in 1996-1997, but there were no further significant decreases in later years.

The long-term fertilization project showed surprisingly little effect of nitorgen on native vegetation in spite of the very high rate of nitrogen input, with major significant effects on native forbs only after eleven years (2004). Since nitrogen fertilization was stopped in 2005, there will likely be a decline in response to nitorgen as soil nitrogen decreases. The grass biomass was up to or beyond 0.8 T/ha of fine fuel in all but the driest years. This is sufficient fine fuel to promote fire (Fenn *et al*. 2003), and may be the most rapid effect of nitrogen deposition. Fires may occur more often in vegetation that has a high fuel load. Once a fire occurs, there is a rapid type-conversion of RSS to exotic annual grassland. In the absence of fire the type-conversion may be slower, as suggested by the gradient analysis where shrub cover and native diversity declined gradually with elevated nitrogen.

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## Assessing Risks of Herbicidal Vegetation Management in a Sensitive Watershed

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### Abstract

Treating invasive vegetation with herbicides can be economical and efficient. However, herbicides can negatively affect ecosystem and human health. In an effort to mitigate risk, it is important to quantify the effects of herbicides on non-target wildlife and the public. This paper presents a risk assessment performed for the Marin Municipal Water District's Vegetation Management Program. The District is considering use of glyphosate (as Aquamaster) and triclopyr (as Garlon 4 Ultra) to control broom and more than 25 additional invasive species. The risk assessment involves three steps: 1) review the toxicology literature to determine toxicity reference values, 2) develop exposure estimates for a variety of human and wildlife exposure scenarios, and 3) compare exposure estimates to toxicity reference values to determine problematic scenarios. Particular emphasis is given to publicly available data and uncertainties in the data. The goal is to provide tools to vegetation managers for performing site-specific risk analyses that protect sensitive resources.

## Introduction

The following paper presents a risk assessment for the Marin Municipal Water District's (MMWD) proposed use of herbicides to control invasive broom. MMWD's primary responsibility is to provide drinking water to Marin County. MMWD manages seven reservoirs and nearly 34 square miles of public parkland. The majority of MMWD land lies between the Golden Gate National Recreational Area and the cities of Marin County. MMWD supports over 30 species that are of special concern, federally listed, or state protected. In addition to providing drinking water, MMWD is charged with protecting and monitoring wildlife and with maintaining fire roads and fuel breaks to protect private property.

One threat to native plants, wildlife and fuel breaks is the encroachment of invasive broom (*Genista monspessulana*, *Cytisus scoparius* and *Spartium junceum*) and over 25 less aggressive invaders. There are approximately 800 acres of broom on MMWD lands. Given that broom spreads rapidly, MMWD is working to limit its spread in a cost-effective and health-protective manner. MMWD has considered numerous control strategies and organized an experts' meeting in February 2008 to discuss management methods. Most broom experts felt that some amount of herbicide use was both necessary and cost-effective for broom abatement.

The MMWD and Marin County residents are particularly concerned with the potential for herbicides to contaminate drinking water reservoirs, thus MMWD commissioned a risk assessment of the potential hazards posed by herbicide use (Kegley *et al.* 2008). MMWD is considering three conventional and two alternative herbicides: Aquamaster (glyphosate isopropylamine salt with no surfactant), Garlon 4 Ultra (triclopyr butoxyethyl ester with a methylated seed oil solvent), Transline (clopyralid monoethanolamine salt), Matran (clove oil derived eugenol), and Scythe (pelargonic acid). The last two herbicides are approved for use in organic production. This paper focuses on glyphosate and triclopyr because these herbicides are among those most commonly used by park managers.

## Methods

A risk assessment consists of determining Toxicity Reference Values (TRVs), estimating environmental exposures for herbicide workers, the public, wildlife and calculating Hazard Quotients (HQs) by dividing the estimated exposures by the TRVs. Risk mitigations are developed to reduce risks where possible.

The TRV provides a dose threshold above which toxicity effects may be observed in a population. A variety of publicly accessible toxicology documents provide a starting point for obtaining TRVs. For humans and wildlife, the EPA Registration Eligibility Decisions (US EPA 1993, US EPA 1998) summarize a chemical's toxicological properties as part of chemical registration. The publicly available USFS risk assessments performed by SERA (Syracuse Environmental Research Associates) (USFS 2003a, USFS 2003b) provide another detailed summary of a chemical's toxicity. Additional toxicological studies can frequently be found in the scientific literature. The biannually-updated EPA Ecotox database (US EPA no date) reviews industry, government, and academic wildlife studies.

To determine TRVs for wildlife, US EPA uses at least one surrogate species to express chemical toxicity for each of the following taxa: mammals, birds, insects, plants, fish, amphibians, aquatic invertebrates and aquatic plants. For some taxa, we found literature studies with lower doses and used these values in order to provide a more protective risk assessment. TRVs were also adjusted downward when only $LD/LC_{50}$ values were available.

Human and animal herbicide exposure occurs through a variety of scenarios which can be distilled into four primary exposure pathways: drinking contaminated water, ingesting chemical residues, dermal absorption and inhalation.

Exposure estimation worksheets provided by the USFS/SERA were used as the starting point for the MMWD exposure estimates.

Hazard Quotients (HQs) are ratios of estimated exposures to TRVs. When HQs are above 1, exposures are likely to affect a population (the adjustment factor of 100 to human RfDs adds extra protection, such that *individuals* are likely to be protected). HQs between 0.1 and 1 may affect a population, and HQs below 0.1 are unlikely to affect a population. It should be stressed that the HQs and the risk assessment are only accurate if TRVs adequately represent the toxicity of the herbicide. When there is less information about a chemical, this approach should be viewed with greater skepticism and interpretation of HQs should be more conservative.

## Results and Discussion

Glyphosate and triclopyr differ in their inherent toxicity, as well as the toxicity of their breakdown products (AMPA and TCP, respectively). Table 1 shows the TRVs for glyphosate IPA and triclopyr BEE.

In addition to being more inherently toxic, triclopyr is more mobile in the environment and has higher dermal permeability than glyphosate. These differences lead to higher HQs for triclopyr for most scenarios. Table 2 presents HQs for human exposure scenarios, and Table 3 presents HQs for wildlife. In each table, there is an additional column showing qualitative probabilities that a given scenario will occur. The probability assessment incorporates MMWD mitigations for preventing chemical exposure.

Triclopyr and glyphosate are frequently used by vegetation managers. Tables 1–3 indicate that triclopyr BEE is considerably more toxic than glyphosate, especially to women, and has higher dermal permeability, which leads to higher worker risk. Herbicide applicators should take every precaution to avoid dermal exposure to triclopyr BEE. Triclopyr is also more toxic to aquatic wildlife. These results indicate that protection of workers, the general public and wildlife is best served by minimizing use of triclopyr products.

| Taxa and Exposure Type | Glyphosate IPA (mg/kg or mg/L) | Triclopyr BEE or TCP (mg/kg or mg/L) |
|---|---|---|
| Humans, acute RfD | 2 | 1.0 male, 0.05 female |
| Humans, chronic RfD | 2 | 0.05 male, 0.012 (TCP) female |
| Mammals, acute | 175 | 100 |
| Mammals, chronic | 175 | 5 |
| Birds, acute | 562 | 65 |
| Birds, chronic | 100 | 10 |
| Honeybees, chronic | 540 | 179 |
| Plants (tolerant), vegetative vigor | 0.56 | 0.0039 |
| Fish (tolerant), acute | 25.7 | 0.013 |
| Fish (tolerant), chronic | 25.7 | 0.075 |
| Amphibians, acute | 6.5 | 6.7 |
| Amphibians, chronic | 1.8 | 1.2 |
| Aquatic invertebrates, acute | 130 | 0.1 |
| Aquatic invertebrates, chronic | 50 | 0.1 |
| Algae (tolerant) | 3 | 0.07 |

Table 1

TRVs for Glyphosate IPA and Triclopyr BEE

Table 2

Hazard Quotients for Selected Human Exposure Scenarios

| | Scenario Probability | Glyphosate IPA HQ | Triclopyr BEE HQ |
|---|---|---|---|
| **Herbicide Applicators, Concentrated Product** | | | |
| Contaminated gloves worn for 1 h | Improbable | 0.0043 | **11.8** |
| Spill on hands, unwashed for 1 h | Improbable | 0.0094 | 0.46 |
| Backpack spraying | Highly Probable | 0.0066 | 0.53 |
| Ground spraying | Highly Probable | 0.022 | 0.90 |
| **General Public, Women and Children** | | | |
| Vegetation contact after spray | Improbable | 0.0011 | **2.80** |
| Contaminated fruit consumption | Improbable | 0.012 | 0.48 |
| Drinking water after 20-gallon spill of concentrated product into Bon Tempe | Highly Improbable | 0.00028 | 0.0012 |
| Drinking water long-term runoff into Bon Tempe | Probable | $6.2 \times 10^{-5}$ | 0.052 |

Table 3

Hazard Quotients for Selected Wildlife Exposure Scenarios

| | Scenario Probability | Glyphosate IPA HQ | Triclopyr BEE HQ |
|---|---|---|---|
| **Terrestrial Wildlife** | | | |
| Direct spray of small mammal, 50% of body | Possible | 0.0027 | 0.30 |
| Eating contaminated fruit by small mammal | Possible | 0.014 | 0.025 |
| Eating contaminated grass by large mammal | Possible | 0.19 | 0.34 |
| Eating contaminated insects by small mammal | Probable | 0.26 | 0.46 |
| Eating contaminated insects by small bird | Probable | 0.13 | **1.2** |
| Eating contaminated prey, carnivorous small mammal | Possible | 0.024 | 0.042 |
| Eating contaminated prey, carnivorous bird | Possible | 0.012 | 0.099 |
| **Aquatic Wildlife** | | | |
| Fish, long-term runoff into Bon Tempe | Probable | $8.5 \times 10^{-6}$ | 0.48 |
| Tadpoles, long-term runoff into Bon Tempe | Probable | 0.00045 | 0.017 |
| Aquatic invertebrates, long-term runoff into Bon Tempe | Probable | 0.000016 | 0.20 |

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## The Impact of the Herbicides Imazapyr and Triclopyr Triethylamine on Larval Bullfrogs


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### Abstract


The imazapyr-based herbicides Stalker® and Habitat® and the triclopyr-based herbicide Garlon® 3A are commonly used to control invasive, exotic plants in wildland settings where non-target amphibian species may be present. Of particular concern is the federally-threatened California red-legged frog, *Rana aurora draytonii,* (CRLF). In order to assess the toxicity risk to amphibians, acute toxicity tests were conducted with the herbicide formulations and their active ingredients, using bullfrog, *Rana catesbeiana*, tadpoles. All of the herbicides, with the exception of Stalker, were found to be within the U.S. EPA's "practically non-toxic" category for aquatic toxic-

ity. Stalker was found to be in the 'slightly toxic' range. The calculated toxicity values were then compared to herbicide environmental concentrations using the risk quotient (RQ) method. RQ values for all herbicides were below the U.S. EPA's level of concern for listed aquatic species. The results of this study indicate that aquatic or adjacent aquatic applications of these herbicides for invasive species control pose no significant acute toxicity risk to larval ranid frogs.

## Introduction

The goal of this study was to develop acute toxicity values for technical imazapyr acid and the imazapyr isopropylamine (IPA) salt products Habitat and Stalker, and technical triclopyr triethylamine (TEA) salt and the triclopyr TEA salt product Garlon 3A to larval ranid frogs. Bullfrog, *Rana catesbeiana,* tadpoles were used as a surrogate for CRLF tadpoles. The toxicity values determined from this study were then compared to known or estimated environmental concentrations. These comparisons allowed us to assess the acute toxicity hazard for each of these herbicides based on the risk quotient (RQ) method. The RQ method estimates risk by comparing an exposure concentration to an effects concentration (exposure/toxicity). The U.S. EPA uses a level of concern of 0.05 to assess acute hazard risks to listed aquatic species such as the CRLF.

## Methods

Static acute toxicity tests (96-h) with 48-h renewal of test solutions were performed following standard procedures. Test chambers were 1000-ml Pyrex® measuring cups containing 400 ml of test solution. Tadpoles were exposed to five different concentrations of each material based on preliminary range-finding tests. There were four replicates per treatment group. Each replicate had ten tadpoles per test chamber with a loading ratio of approximately 0.40 (g/L) at a temperature of 22°C. Test solutions were analyzed for active ingredient concentrations by gas chromatography-mass spectrometry (GC/MS). The $LC_{50}$ values were based on concentrations of active ingredients in the commercial products. Results for the imazapyr IPA salt products Habitat and Stalker were converted to acid equivalents in order to provide simplified comparisons to the technical (acid) product.

## Results and Discussion

Based on 96-h $LC_{50}$ values, all of the compounds, with the exception of Stalker, were within the U.S. EPA's "practically non-toxic" category for aquatic toxicity. Stalker with an $LC_{50}$ value of 14.7 mg/L was found to be "slightly toxic". The $LC_{50}$ values for Garlon 3A and Habitat were 174.5 mg/L and 1,739 mg/L, respectively. The toxicity values for the technical compounds imazapyr acid and triclopyr TEA salt were 799.6 mg/L and 814.1 mg/L, respectively.

In order to more accurately assess acute toxicity risk, we determined RQ values by dividing each compound's highest known or estimated concentration in water by its $LC_{50}$ value. A concentration of 0.50 mg/L was used for imazapyr[1] and 3.5 mg/L was used for triclopyr TEA[2]. The resultant RQ values for the formulated products Stalker, Garlon 3A and Habitat were determined to be 0.027, 0.020 and 0.0002, respectively. RQ values for technical imazapyr and technical triclopyr TEA were 0.0005 and 0.0004, respectively. All of these RQ values are below the U.S. EPA's level of concern for listed aquatic species (0.05). These results indicate very low acute toxicity risk to larval frogs present in aquatic sites that receive direct applications of these herbicides. The risk posed by indirect exposure routes (i.e. drift from terrestrial applications) would be even less.

[1] 2006 San Francisco Estuary Invasive Spartina Project, highest detected residue for imazapyr in water.

[2] US Forest Service estimate for maximum triclopyr TEA exposure in water.

## Monitoring a Declining, Hybridizing Weed

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Eradication of the highly invasive hybrid between introduced Atlantic Smooth Cordgrass (*S. alterniflora*) and native Pacific cordgrass (*Spartina foliosa*) has been the mission of the San Francisco Estuary Invasive *Spartina* Project ISP) since its inception eight years ago. As the ISP Control Program successfully coordinates regional treatment of invasive *Spartina*, the ISP Monitoring Program is challenged to detect and document the remaining weakened and fragmented populations of this once obvious invader. Invasive *Spartina* has become more difficult to identify not only because of successful control efforts, but also because of the selection for highly backcrossed, morphologically "cryptic" hybrid plants. After over 10 generations of backcrossing, it has become difficult if not impossible to distinguish some hybrid plants from native plants in the field. Our monitoring methods use GPS-intensive field methodologies combined with lab-intensive DNA testing to assist with the detection and ultimate eradication of the invasive *Spartina* remaining in the San Francisco Estuary.

## Invasion Potential of Chinese Tallow (*Triadica sebifera*) in California

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### Abstract

*Triadica sebifera*'s aggressive spread in the southeast U.S. over the last 200 years has transformed grasslands and riparian areas into monocultural stands. Recent discovery of naturalized populations of *T. sebifera* along the American River and several other locations in the Central Valley have raised red flags about the potential for a serious invasion in California. Climate modeling also indicates that most of California's riparian habitat is susceptible to invasion. To understand more precisely where invasion could occur we conducted field tests of invasion potential of *T. sebifera* along an elevational gradient at Putah Creek, a San Francisco Bay-Delta tributary, using both germination and initial seedling growth/survival. Simulating the most common dispersal scenarios (by birds, water, and gravity) we found substantial germination in all treatments and controls at all elevations. Finding no barriers to germination, we investigated initial seedling growth using young seedlings transplanted from a greenhouse into the field over the same elevational gradient. After five months, only seedlings planted adjacent to the creek were alive, but these had grown rapidly and appeared healthy. Drought was the suspected cause of death in almost all cases. These results suggest substantial invasion risk in perennially moist areas—a potentially grim conclusion for California's riparian regions.

### Introduction

*Triadica sebifera* L. Small [*Sapium sebiferum* L. Roxb.], Chinese tallow tree, is native to eastern Asia, but has naturalized along the Gulf Coast of the southeastern United States where it invades wetlands, prairies, woodlands and forests (Bruce *et al*. 1997). In this adventive region, it enriches soil (Cameron and Spencer 1989) and dominates communities often to the point of monospecificity (Jubinsky and Anderson 1996; Bruce *et al*. 1997). The Z-score, a predictor of woody plant invasiveness (Rejmánek and Richardson 1996), was calculated as +7.83 for Chinese tallow by Jaryan *et al*. (2007) predicting high invasiveness for this species.

Recent climate modeling suggests that much of California's riparian habitat is suitable for Chinese tallow (Pattison and Mack 2008). This suitability is supported by recent discoveries of naturalized populations in California's Central Valley. These naturalized populations seem to be restricted to perennially moist areas. Though Chinese tallow is sometimes cited as being tolerant of dry conditions, invasion seems to start near perennial water bodies. To better understand where Chinese tallow can invade, we conducted germination and seedling growth experiments along Putah Creek, a Bay-Delta tributary. We also evaluated vertebrate and invertebrate herbivory on transplanted seedlings as no such studies have been conducted in California.

### Methods

***Germination*** Experiments were conducted at Putah Creek Reserve along five elevational transects placed between the creek edge and the high water mark. Seeds were pre-treated with simulated common dispersal scenarios (water – 30-day soak; bird gut passage – acid soak; gravity – no treatment) and sown in lots of 20 seeds at 2cm depth in March 2007. Seeds were watered only initially and recovered 30 days later. Recovered seeds were immediately assessed for germination (radical emergence) and ungerminated seed was cracked open to evaluate viability. The effects of treatment and elevation were analyzed using a factorial ANOVA. Environmental factors suspected to influence germination were also assessed and their quality as predictors evaluated.

***Seedling studies*** Seedlings reared in a UC Davis greenhouse were transplanted into the same plots and transects used in the germination experiment along Putah Creek. Seedlings were watered only initially to minimize transplant effects. Seedling height was assessed regularly until the return of rain in October, when all plant material was removed. Above-ground vertebrate herbivory was evaluated by placing half of all seedlings in wire exclosures. Above-ground invertebrate herbivory was evaluated by recording estimated biomass removal from caged seedlings approximately every week. Seedling mortality occurred when all leaf mass was dry and stems were withered.

## Results and Discussion

***Germination*** Germination at the end of one month averaged 38.2% over all plots. A factorial ANOVA revealed significant effects of elevation ($p=0.0033$) and seed pretreatment ($p<0.0001$) with no significant interaction. Germination after acid treatment and gravity dispersal was significantly higher than for seeds removed directly from trees (Tukey HSD means separation; $p<0.05$). Substantial amounts of germination were observed across all pre-treatment-elevation combinations. Especially because the experiment was run for only 30 days (and many remaining viable seed would have germinated had we run the experiment longer), we conclude that there are no significant barriers to Chinese tallow germination along Putah Creek. We suspect that the significant effect of elevation on germination was due to soil water content and temperature and an analysis to identify such factors that promote Chinese tallow germination in the field is currently underway.

***Seedling studies*** Only seedlings transplanted immediately next to the creek survived until the end of the experiment in October. These survivors appeared healthy and had grown as tall as 56cm before they were removed. Most plants at higher elevations had died by 42 days after transplanting and these tended to exhibit wilting and slowed or no growth prior to death. These findings indicate that a barrier in the form of excessive drought stress may preclude Chinese tallow from establishing far from perennial water bodies. Our second elevation was only 1.14m above the creek edge and all of these seedlings died early in the experiment.

Herbivory was not a significant factor in plant survival though 59% (118) of plants experienced some degree of above-ground invertebrate herbivory, usually very slight. Only one plant (uncaged) experienced the massive, contiguous above-ground removal of biomass indicating potential vertebrate herbivory. These results are consistent with finding from other studies in different regions of the world where herbivore resistance has been documented.

***Study implications*** Though germination occurred over all elevations we examined, it was poor seedling survival at higher elevations that restricted Chinese tallow to the creek edge in our study. These results indicate that Chinese tallow is very capable of invading riparian areas adjacent to perennial water bodies in California's Central Valley, but highly unlikely to colonize dry upland habitat. A restricted potential for invasion is good news, but in the Central Valley of California where we performed this work, it is estimated that only a tenth of original riparian habitat remains (Katibah 1984). These habitats host high biodiversity and are crucial to many threatened species (Brode and Bury 1984). Transformation of these critical habitats into *T. sebifera* monocultures, as has commonly occurred in the Southeast, is therefore likely to eliminate populations of wildlife and invertebrates and result in depauperate species communities. Our study therefore serves as a word of caution for land managers and horticulturalists and as strong justification for increased vigilance and control efforts directed at this species. As Chinese tallow trees continue to be planted in the Central Valley, and as both naturalized and planted individuals mature and produce more seed, we may expect the establishment of new naturalized populations and increased spread along perennial water bodies in California's Central Valley.

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# Steal This Protocol: The Invasive Plant Species Early Detection Protocol for the San Francisco Bay Area Network of National Parks


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## Abstract

The San Francisco Area Network of National Parks (SFAN) includes Point Reyes, Golden Gate, Pinnacles, and several smaller parks. The network supports collaborative monitoring; a protocol for the early detection of invasive plant species was field-tested over the past few field seasons. Park units were broken into subunits that allowed managers to quantify baseline invasive plant information. Subunits were ranked by number and degree of current infestations, risks of further infestation, priority of resources present, and other characteristics based on information available and management priorities. Invasive plant species were ranked based on ease and feasibility of control, and high-priority species placed on lists for early detection throughout the park, or detection in currently uninfested areas. Surveys were targeted in high-risk or high-priority areas, and plant occurrences mapped according to the protocol using the GeoWeed database and its ArcPad applet. Negative data, points, and polygons were collected for priority species, and presence/absence by subunit gathered for lower-priority invasive species. Pilot-year results informed list, protocol and methods revisions; the protocol is being peer-reviewed and will be publicly available for use, as will supporting training materials and identification cards. Rankings and survey results will also be used to inform restoration and removal activities.


## Introduction

Federal (FICMNEW 2003), state (CDFA 2005), non-governmental agencies, academics, and others (Rejmanek and Pitcairn, 2002; Timmins and Braithwaite 2002) agree that early detection, aside from prevention, is the most efficient invasive species strategy. But while many recommend doing it, few delineate how.

The San Francisco Bay Area is part of one of the six most significant areas in the nation for biodiversity; human population and the area's place in global trade both place exotic species propagule pressure on the national parks in this region. Prioritizing prevention, early detection, and rapid response, while continuing ongoing control, will allow the parks to deal with invasive plant species in a more cost-effective and strategic manner. The protocol discussed presents logical methods and guidance for where, how often, and for what to search; the types of data to gather; and recommended training levels for volunteers and staff, to better glean data from some of the millions of people out in our national parks annually.

## Methods

Three objectives provide the framework for early detection monitoring: 1) developing and revising a list of target invasive plants, whose priority determines the level of data gathered; 2) ranking park subwatersheds (management subunits) by management priority, risk, and current infestation level to generate priorities for monitoring frequency; and 3) regularly evaluating and examining invasive plant monitoring data to revise and refine priorities, as well as clarifying contributing factors to new invasions in the park.

The list of target species for each park was based on current knowledge and rankings, summing recognized invasiveness and biological ease of control and stratifying into priorities by feasibility of control based on species' (estimated) infested acreage in the park. A list of all exotic species known or thought to occur in the parks (~300 species), compiled from NPSpecies, was the base list. After removing known non-invasive species, and species locally non-native, 174 species remained. Species listed by the California Invasive Plant Council (Cal-IPC), California Department of Food and Agriculture (CDFA), The Nature Conservancy (TNC) and local Weed Management Areas received varying numbers of points for invasiveness, as did unlisted species which shared invasive characteristics with a listed species in the same genus. Based on best available knowledge, species also received points for altering ecosystems—affecting a system change, not just crowding out other plants—and for endangering rare plants in SFAN parks. Next, based on best available knowledge, species were ranked by biological ease of control independent of number of acres infested. All points were summed for the overall invasiveness score, then sorted according to feasibility of control based on estimated number of acres infested with that species, cost for removal, politics, and access. "Controllable" acreage was based on the size of the park unit and annual area treated by their exotics program, and varied slightly by park. Species shown to be highly invasive, but not widespread in the park, are top priority for detailed mapping; more widespread but still invasive species are mapped with a point unless populations are small.

The list of priority areas for searches was made by ranking subwatersheds—drainage-based subunits of watersheds—by number and degree of current infestations; risk of further infestation; and priority of resources present. Subwatersheds were ranked, grouped along the most natural breaks, and assigned a score. Total score was obtained by adding risk to weighted (2x) rare species priority score and subwatersheds approximately quartered into high, significant, moderate, and low priority. High-priority subwatersheds are visited annually; significant and moderate, biennially; and low, once every five years.

Surveys cover roads and trails, with data collection ranging from simple (presence/absence during a survey) for low-priority species or Level 1 volunteers to complex (digital point and polygon data, as well as associated phenological and habitat data, taken with a handheld unit) for highly skilled volunteers and staff and high-priority species. Information is stored in GeoWeed, Sonoma Ecology Center's improvement on The Nature Conservancy's Access-based vegetation management information system WIMS. GeoWeed (http://geoweed.org), like WIMS, is freely available and allows for digital data collection through a series of ArcPad forms (ArcPad is not free). Negative data are tracked through the use of the "Survey Area" portion of the database, as well as GPS tracklogs associated with a coded survey area ID.

Data acquired from surveys may be time-sensitive. Acting upon new detections of invasive species is critical, so monthly reports go out to park staff and interested parties in addition to working towards sharing a common database. Annually, all staff involved with invasive species work should meet to review maps for completeness and accuracy, and to provide feedback on the early detection program. Annual reports include number of occurrences by subwatershed and by species, and the time spent surveying and miles covered; maps of locations and presence/absence of species by subwatershed; and revisions to the species.

Outreach and collaboration are essential to the protocol. Additional products for non-vegetation staff and the public include presentations and trainings on priority invasive species; laminated "Plant-out-of-Place" priority species identification cards, lists with photographs of invasive plants found during surveys; and articles and presentations. Collaborations include local Weed Management Areas and the Bay Area Early Detection Network, an expansion of park-based early detection to lands throughout the Bay Area.

### Results and Discussion

Since this is a presentation of a protocol, much of the interest should be in the "Methods" section – although in this case, the protocol is also a result. Results from the first few field seasons show a great deal of error associated with estimates of how common exotic species may be, and list adjustments continue to be made. Such error is to be expected without a baseline inventory of all exotics. Also, the highest-priority species list was split into two lists: one for species with few occurrences, and one with no known occurrences: the former is appropriate for volunteer-based searching, as the search image should be reinforced through occasional finds; the latter list is reserved for staff and/or more expert botanists.

All program materials, including the protocol, ID cards, "Weed Watcher" manual and data sheets, and results maps, are or will be posted on the SFAN website http://science.nature.nps.gov/im/units/sfan/vital_signs/Invasives/invasives.cfm.

The San Francisco Bay Area Network is a complex case, so application of this protocol should be simpler for many sites. There should be fewer worries about communicating findings to others, or ensuring all cooperators can share a database, as in many cases the staff doing detection, recording and response is the same person.

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## Stop-the-Spread of Yellow Starthistle into the Sierra Nevada Mountain Range – Early Detection and Eradication on a Regional Scale

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### Abstract

Yellow starthistle (*Centaurea solstitialis*) is one of the most ecologically and economically damaging invasive plants in California. Although areas of California remain uninfested, yellow starthistle (YST) has shown it can invade most bioregions. YST has invaded the foothills of the Sierra Nevada Mountains and is poised to expand into the higher elevations including the Lake Tahoe Basin and Yosemite National Park.

A coordinated, regional project to control YST populations at an eastern leading edge line across fourteen foothill counties (Plumas to Kern) was initiated by California Department of Food and Agriculture in 2007. This project is one of the first in California to address invasive species in a coordinated manner over a large region. Project elements include: 1) surveying, mapping and control of YST at the eastern leading edge, 2)

detection and eradication of outlier YST populations beyond the "no-spread" line, 3) establishment of a centralized GIS database to document results and 4) "Yellow Starthistle Prevention Areas" along the YST stop-the-spread line with educational signage and contact information for when YST populations are detected in the designated area. By implementing a regional-scale early detection and eradication plan utilizing the Weed Management Area (WMA) infrastructure and a project coordinator, collaboration among landowners and local, state and federal agencies has increased to utilize resources more effectively.

## Introduction

Yellow starthistle is capable of growing, and has been detected in small populations, at high elevation locations in California's Sierra Mountains including the Lake Tahoe Basin and Yosemite National Park. It has long been the consensus of the invasive weed community that the coordination of early detection and rapid response strategies are key in preventing the spread of invasive weeds (California Department of Food and Agriculture 2005). The Sierra Nevada Mountains and their important natural values - 12.9 million acres of public lands, 48 threatened and endangered plant and animals species, timber production and recreational and property values – can be protected by stopping the eastern spread of YST along a "no-spread" line in the fourteen-county Sierra foothills region.

In 1999 and 2000 California Department of Food and Agriculture (CDFA) conducted a YST detection survey along major and secondary roadways in the Sierra Nevada foothills. Based on this baseline data, several counties in the region have established YST leading edge "no-spread" lines and identified outlier populations to eradicate east of the leading edge line. The goal of this project is to expand these detection survey, mapping and control/treatment efforts across the entire foothill region.

## Methods

A project coordinator from University of California Cooperative Extension was contracted by CDFA to facilitate grant administration, federal, state and local stakeholder and agency coordination, and to identify the barriers and needs of the local WMA to participate and succeed in implementing the project. Twelve WMA groups within the region developed work plans and received $5000 mini-grants for survey, mapping and/or control/eradication work during the 2008 field season. Lead agencies on the project included County Agriculture Departments, University of California Cooperative Extension and Resource Conservation Districts. Six WMAs completed detection survey and mapping work to produce a baseline data set for their county, while the remaining WMAs completed survey and mapping of historical populations plus treatment of YST. Priority areas for survey and mapping included: burned areas, construction and road development sites, high risk areas near threatened and endangered species, important wildlife habitat and high value timber and recreation areas.

The project coordinator worked with each WMA to identify barriers and needs to implement the leading edge project successfully. Identified needs included: 1) long-term funding for on-the-ground survey and control/eradication activities; 2) challenges in hiring trained, seasonal and/or part-time staff to complete the work; 3) Global Position System (GPS) and Geographic Information System (GIS) mapping training; 4) improved coordination with agencies and large landowners at the local, state and federal levels; 5) additional control and eradication tools are needed, including the use of herbicides, which could require additional environmental assessment documentation by state and federal land management agencies; and 6) engagement of private landowners and access to private lands.

## Results and Discussion

Mapping data from 2000 to 2007, beyond the roadway data collected by CDFA in 2000, was collected from the foothill counties, when available, and incorporated into the California Department of Food and Agriculture (CDFA) YST database. Initial analysis of the data revealed that

YST moved east and gained 1200 feet in elevation along Highway 4 in Calaveras County between 2000 and 2007 – a good example of YST "marching" into the Sierras when left unchecked.

Mapping training was conducted for 25 WMA participants in March 2008. Mapping data from 2008 was collected from counties in the region and from state and federal agencies, including Bureau of Land Management, six National Forests and Yosemite and Sequoia-Kings National Parks. Additional data will be collected in October 2008 from utility districts (including Pacific Gas and Electric) and large private landowners such as Sierra Pacific Industries. To date, 24,700 gross acres and 2,950 miles of roadway have been surveyed and mapped for YST. Treatment in the region has included hand pulling YST on 24 acres and 41 miles of roadway and treating 137 net acres with herbicide. Educational and outreach efforts have reached 1950 landowners via surveys, workshops, informational booths at events, presentations at commission and homeowner associations meetings and during site visits with private landowners.

Each WMA will be evaluating mapping data at the local level to define their "no-spread" line from maps produced by CDFA. We will then "connect the dots" to delineate a regional YST leading edge line and identify priority outlier infestions beyond the line for eradication.

Three areas have been identified as candidates for establishment of "Yellow Starthistle Prevention Zones": 1) Ice House Road, near Highway 50 and the Crystal Basin recreation area in El Dorado County; 2) Highway 198 at Three Rivers near the entrance for Sequoia-Kings National Park in Tulare County; and 3) on Highway 140 near El Portal at the entrance to Yosemite National Park in Mariposa County. Road signage and an outreach campaign are currently under development with completion expected in October 2008.

Project updates can be found at the CDFA Encycloweedia webpage at www.cdfa.ca.gov/phpps/ipc/encycloweedia/encycloweedia_hp.htm

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## Application of Feral Animal Eradication Techniques to Invasive Plants: Early Detection and Rapid Response

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There are few large-scale success stories where land managers have outpaced invasive species spread and establishment. Early detection and rapid response (ED-RR) is considered the most effective method to address the onset of an invasion since the costs to tackle incipient weed populations are much less than managing established widespread weeds. Implementing ED-RR programs although effective can be time consuming and expensive, with more time spent searching for and accessing populations than treating them. Recently, a New Zealand based firm, Prohunt Incorporated, eradicated over 5,000 feral pigs from Santa Cruz Island, California in only 22 months with the support of a small two-person helicopter, demonstrating that eradication projects once thought to be impossible are achievable. Their feral animal ED-RR techniques were modified, to systematically survey for 55 invasive plant species across the island in 2007, and to treat 14 species to zero density in 2008 by their California-based sister company, Native Range Incorporated. The ED portion of the project, which also served as a baseline survey, took only 41 days to complete, and the RR portion required only one month to treat over 360 populations, using a helicopter to transport or "leap frog" workers directly to weed infestations. Weed workers treated infestations quickly, thus conserving energy to tackle subsequent populations and conduct ad hoc weed surveys while in transit from one infestation to the next. The systematic use of a small, highly-maneuverable helicopter for EDRR programs is the advancement that will allow land managers to detect and treat all individuals, and outpace invasive plant establishment – necessary requirements for eradication.

# Learning from the Past

## Native Californian Use of Fire in Weed Management

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### Abstract

Management of weeds poses a significant problem for various cultures globally. Undoubtedly Native Californians identified native weeds, which were managed frequently with fire, to keep them at bay. Since European arrival a vast array of new invasive species have colonized the landscape, and have created management challenges for Native Californians and others now living in this region. While Native Californian land tenure has changed over the last several hundred years, the concern for resource management has not and there are numerous examples of Native Californians interest and activity in weed management traditions. The considerations of traditional fire management and the response of vegetation to the parameters of fires pose a unique and appropriate tool for contemporary land managers. Case studies in traditional fire use will be examined with a primary focus on riparian management.

### Overview

The California floristic province shares a similar boundary with the cultural province of Native California; that is they extend westward from the Peninsular, Transverse, Sierra Nevada, and Southern Cascades from present day Baja California into Southern Oregon. Where one supports approximately 2,153 endemic plants, the other supported more than 100 distinct languages. The co-occurrence of this richness is tied not only to the physiographic inputs and feedbacks of this region, but also the cultural influences that indigenous people have implemented through the millennia. Martin and Sapsis (1992) suggested that the patterns and processes of indigenous burning in California created and maintained biodiversity. Fire was one of several tools used by Native Californians to manage their landscape (Anderson 2005).

When Spanish explorers sailed along California's coast in 1542 and later settled in 1769, they observed a land that was tended to by Native Californians. Presumably, in this same time period the invasion of California by non-native plants was initiated both accidentally and intentionally. Changes in fire use driven by factors such as the introduction of livestock, development of anti-burn policies ( Stephens and Sugihara 2006) and indigenous population declines were all likely facilitators in the invasion of California's ecosystems by non-native species. The invasion process was rapid and masks our knowledge of what the exact native species composition was in grasslands (Randall and Hoshovsky 2000) and many other ecosystems.

### Plant invasion in Native California

The term 'weed' refers to any plant that is culturally undesirable. Prior to the arrival of Spaniards to California, Native Californians also had weeds to contend with. While these weeds were native species, they were none-the-less culturally undesirable. Anderson (2005) describes how invading conifers were hand-pulled from mountain meadows; and similarly, how sedge beds were groomed to remove competing species. The consequences of management actions could shift the species composition of an area depending on factors such as seasonal timing, climate feedbacks, seed dispersal, banking, and survival of vegetation.

Livestock have been implicated for the spread of many invasive species into the landscapes of California. Invasive species seeds have been dispersed as undigested material in feces and on the coats and hooves of livestock. The inoculation of the landscape by seeds of non-native plants dispersed by livestock likely benefited from patches of recently burned grounds created by indigenous people. Furthermore, the foraging behavior of different stock was detrimental to some native species and likely led to the localized decline of native flora. Considering the frequent early germination of many non-native species observed in many regions of California, it is assumed that many non-native species secured a competitive advantage. Furthermore, some native plants (*e.g.,* bunchgrasses) are prolific biomass producers. Frequent fires removed detrital material and facilitated photosynthesis by doing so. Fires have also been linked to increased inflorescence production; hence more seeds. When fire is removed many native species decline.

### Management Techniques and implications

Fire use in Native California was a year round affair. Frequently, fires were set in many ecosystems during the fall and winter months, but other fires were set during the spring and summer months. The purpose and scale of these fires varied by seasonal burn objectives and needs. Most early wet season burning was for maintenance of areas, whereas dry season burns were set for activities such as clearing areas and hunting. Lewis (1973) identified over 70 uses of fire by California Indians. Various uses would have been applied specifically within prescribed seasons. Within vegetation types this created a mosaic of age class structures and heterogeneity of species assemblages (Martin and Sapsis 1992, Parr and Anderson 2006). In some areas the seasonal variation of patch burns may have facilitated colonization by invasive species. We now understand that once established some non-native species facilitate the alteration of fire behavior and frequency (*e.g.,* Syphard *et al*. 2006).

### Integration of weeds into traditional culture and cultural differences

Just as settler cultures brought plants with them, Native Californians learned which of these plants were useful and incorporated them into their traditional knowledge. The decline of many native species required adaptation to new plants to fulfill dietary needs and to produce material cultural items. Many early ethnographies (*e.g.,* Barrett and Gifford 1933) note the inclusion of non-native plants for food, medicine, and basket production. For instance the culms of wild oat (*Avena fatua* and *A. barbata*) were used to create the bundle foundation of some coiled baskets.

The under-appreciation for native plants by non-native settlers has been problematic for the continuation of traditional culture by Native Californians. Many native plants identified as weeds in references such as Whitson et al. (1996) are in fact culturally significant to Native Californians. For instance, every part of the common cattail (*Typha latifolia*) was historically used for food, medicine, fiber or other uses. Less common plants such as showy milkweed (*Asclepias speciosa*) and dogbane (*Apocynum cannaninum*) are highly sought fiber plants used in net making and production of dance regalia. These plants are so rare for many cultural practitioners to find in quantity that commercial fibers are frequently used as a surrogate.

While management of invasive species is important for maintaining native flora and fauna, the techniques for management are not necessarily mutually amenable. Contemporary management of invasive species is of concern to Native Californian traditional cultural practitioners. Specifically, there are concerns about collection of food, medicinal or fiber plants which may be contaminated by herbicide treatments. Several studies and reports have documented these concerns and some have attempted to address the level of threat to various tribal communities (DPR 2001, Norgaard 2007).

### Applications of Traditional Burning

Contemporary land management has been slow to restore cultural fire use as a tool. In recent years, projects involving indigenous populations and/or indigenous-style fire managements have occurred at several locations throughout Central and Northern California in riparian woodlands (*e.g.,* Hankins 2005, Lake 2007) and blue oak savannas. Generally, these studies have documented an initial increase in native species richness (primarily perennial grasses and annual herbs) following early wet season burns. Conversely, an increase in non-native forbs has been observed following some early dry season burns (J. Rowden pers. comm.). The application of indigenous land management methods for invasive and/or non-native species control is a viable alternative for many species.

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## History of Herbicide Use and Development of Herbicide Resistance


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### Abstract


Salt may have been the first chemical recognized as an herbicide when it was used to kill unwanted plants (prevent crop growth) when the Romans brought down Carthage in 146 BC. Salts of the metallic compounds, copper, iron and arsenite were used in the early 1900's to control water hyacinth in the southern US and broadleaf weeds in cereals. But it was not until 1941 with the discovery of 2,4-dichlorophenoxy acetic acid (2,4-D) and closely related MCPA that relatively small amounts of a chemical could selectively kill a group of plants while sparing others. Soon after came phenyl substituted ureas (monuron) in 1951, the corn herbicides (triazines) in 1955, dinitroanalines such as trifluralin (Treflan) in the 1960s, glyphosate (marketed as Roundup) in the late 1970's, sulfonylureas (ALS inhibitors) marketed in early 1980's. Originally used in agroecosystems, modern herbicides began to be used in rangelands around the late 1950's and in wildlands in the 1960's. Every class of modern herbicide has examples of weeds that are resistant to their modes of action. The rate of herbicide resistance is a function of duration of herbicide exposure due to frequency of application and residual activity, force of selectivity and whether tolerance/resistance is genetically determined. Resistance to the triazines was first recognized in the 1970's most likely because of frequency of application and long residual activity of this group of herbicide. Herbicides such as the ALS inhibitors that act on single gene traits where there are several mutations, each one of which confers tolerance, are more likely to see resistance develop quickly, often within a decade of their introduction.

## Herbicides Before 1940

The development of herbicides and mechanization represents a period in history that relieved most of the American population from the rigors of food production on a farm. The first use of herbicides was for non-selective control of unwanted vegetation on non-cropland or around cropland. Salt may have been the first chemical recognized as an herbicide when it was used to kill unwanted plants (prevent crop growth) when the Romans brought down Carthage in 146 BC. Sodium nitrate, ammonium sulfate, iron sulfate and salts of copper were tested in the early 1900s for selective broadleaf control in Europe in cereal crops. Limited used was made of sulfuric acid on cereals and onions but the problems associated with handling a strong acid prevented wide-scale use.

Nonselective herbicides, such as arsenic, orchard heating oil, salt (sodium chloride), sodium chlorate and carbon bisulfide as a fumigant, were the available remedies, primarily for perennial weeds. The application rates of these compounds seem tremendous as compared to today's herbicide use rates. Salt was used at 20 tons/A or more, sodium chlorate at 600-1000 lb/A, carbon bisulfide at 320 gal (3200 lb)/A, heating oil at 100-300 gal/A, and arsenic in various forms applied at several pounds as sodium arsenate or at hundreds of pounds as dry white arsenic.

## Herbicides after 1940

As a result of plant hormone research conducted in the 1930's and efforts to develop compounds to control vegetation during World War II, (2,4-dichlorophenoxy) acetic acid (2,4-D) and its close relative MCPA were discovered in 1944. They were capable of destroying annual weeds at application rates of a few ounces per acre, and certain perennial weeds at slightly higher rates. Moreover, they could be used selectively to control broadleaved weeds in corn, small grains, grass pastures, and lawns. The phenoxy compounds were translocated in the plant and could cause destruction of deep roots of perennial weeds; they could be applied at low volume by ground or air. Indeed, they appeared as miracles to those weed workers who had labored with pounds and tons per acre of nonselective, soil-acting herbicides.

Other phenoxy compounds such as silvex and 2,4,5-T were introduced and used in forest management. They were later pulled from the market because they were contaminated with a highly carcinogenic form of dioxin and due to the negative publicity associated with Agent Orange which was used as a defoliant in the Vietnam War. In 1951, phenyl-substituted ureas such as monuron and diuron were discovered. The triazines such as atrazine and simazine were developed in 1955 and soon after became very commonly used to control broadleaf weeds in corn. Dinitroanalines such as trifluralin (Treflan), were marketed in the 1960s. Glyphosate (marketed as Roundup) was developed in the 1970s to provide non-selective control of the more difficult to control perennial weeds. The lack of soil residual activity meant that crops could be planted soon after its application. Glyphosate became much more important in agriculture following the introduction of herbicide tolerant crops in the mid 1990s. The 1980s were marked by the introduction of the selective herbicide groups including the sulfonylureas, imidizolinones, and the aryloxyphenoxy propionates which could be applied at very low rates. The sulonylureas, chlorimuron and primisulfuron are used at a fraction of an ounce per acre.

Although most herbicides were developed for use in agroecosystems, modern herbicides began to be used in rangelands around the late 1950s and in wildlands in the 1960s. Many of the chemical methods developed for use in ornamental plantings and noncrop sites may be used in wildlands because all of these systems are not managed for the production of food or fiber commodities. However, always follow the herbicide label before applying an herbicide because certain compounds may be restricted from use, especially when their use could contaminate water or pose a significant threat to non-target aquatic life.

## Herbicide Resistance

Herbicide resistance is the inherited ability of a plant to survive the dose of an herbicide that would normally kill the wild type. The herbicides are not thought to cause mutations that lead to resistance; genes conferring resistance are naturally present in wild populations. The weed characteristics that contribute to the rapid development of resistance are annual growth habit, high seed production, high germination rates, many seed flushes per year, extreme susceptibility to the herbicide in question and a high frequency of resistant genes. For example, the rapid increase in resistance to ALS herbicides is attributed in part to the high mutation frequency in the target site enzyme and the existence of several mutations that can confer resistance. Herbicide characteristics that contribute to the rapid development of resistance are:single site of action, long residual activity in soil, and rapid and effective kill of many weed species. Any process that contributes to the increased exposure of a weed population to the killing power of an herbicide, be it frequency of use or long residual, will result in more rapid development of resistance.

The first recognized case of herbicide resistance was a triazine resistant biotype of common groundsel (*Senecio vulgaris*) in the late 1960's (Figure 1). The triazines were a very commonly applied herbicide because of their use in corn. They have long residual activities because they do not break down rapidly and are used repeatedly in continuous or near continuous corn crops. Resistance is conferred by a mutation in a gene that ultimately prevents the herbicide from binding to a photosystem protein. Since that time, resistance has developed in every major herbicide group based on modes of action. Currently there are 321 unique biotypes of resistant weeds representing 185 species (111 dicots and 74 monocots) and over 290,000 fields (www.weedscience.org). There are currently 67 biotypes of weeds that are resistant to the most common mode of action, photosynthetic (PSII) inhibition, which is the mode of action for triazines. The ALS (acetolactate synthase) inhibitors such as the sulfonylureas, imidizolinones, pyrimidinyloxybenzoate, and triazolopyrimidines have 95 resistant biotypes, the highest and most rapidly developing of all herbicide groups. Many herbicides

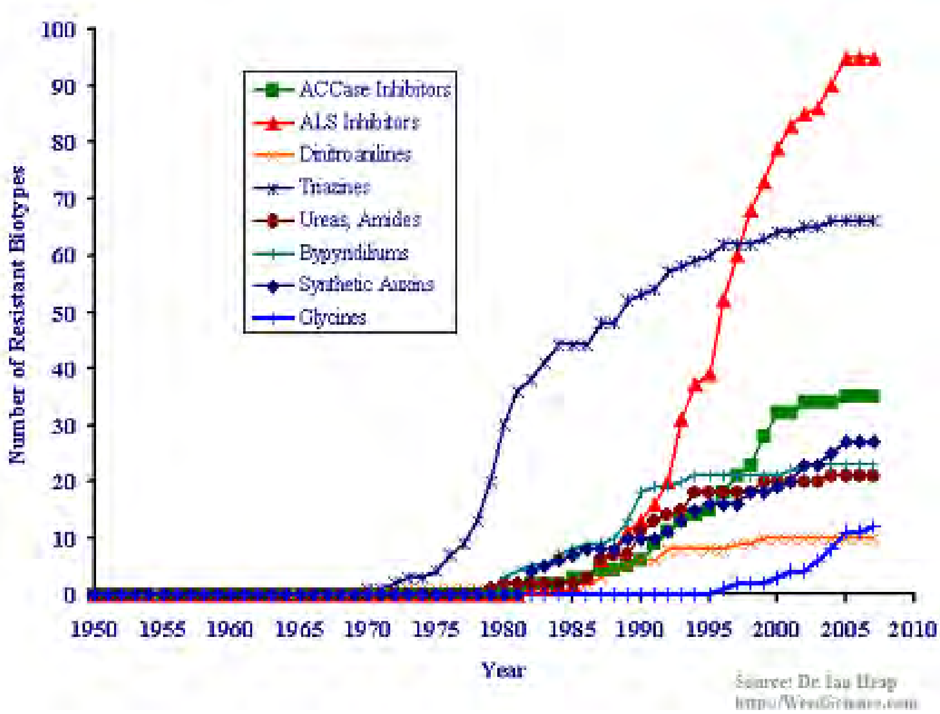


Figure 1

Development of herbicide resistant weeds beginning with triazines in the late 1960's (Source: Ian Heap. www.weedscience.org) used in wildlands are represented by these groups of herbicides (Figure 1). Resistance to the ALS inhibitors may be due to the 10 or more mutation sites on ALS that confer resistance.

Many of the grass-specific herbicides from groups such as the arloxy phenoxy propionic acids and cyclohexanediones inhibit ACCase (acetyl CoA carboxylase). This mode currently has 35 resistant biotypes, the third highest behind the ALS and PSII inhibitors. It was thought that resistance would be very slow to develop to glyphosate because of its unique mode of action, the lack of mutations in the target gene that could confer resistance, that the herbicide binding site may be very close of the same as the substrate binding site. However, that situation changed when a resistant biotype of rigid ryegrass (*Lolium rigidum)* was discovered in 1996 in Australia and then again in California in 1998. The mechanism of this resistance has been identified as a target site mutation that prevents glyphosate from binding and yet allows binding by the substrate necessary to catalyze the production of aromatic amino acids.

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# Discussion Group Notes

## Careers in Wildland Weed Research and Management

Discussion leader: Chris Christofferson

Note taker: Heather Schneider, UC Riverside/Cal-IPC Student Chapter

*This discussion group will provide an informal venue for questions, answers and the exchange of ideas about the future of careers in wildland weed work. This session will complement the more formal panel discussion scheduled for Friday at 1:30. Many of Friday's panelists will be present in a more approachable, small-group setting. This group is suitable for aspiring weed workers, for natural resource managers of all sorts and for academics (both students and teachers).*

*How can you find jobs and make connections?*

- join job listserves
- usajobs.org
- self-advertise
- be persistent
- don't be afraid to call an agency you would like to work at, even if they do not have any jobs posted
- meet people and build your own career, many times, it's who you know
- network!
- Cal-IPC Student Chapter is planning to post jobs on their future website
- be specific when talking about your interests, people don't like wildcards

serendipity

*What are employers looking for when they interview potential job candidates?*

- Generally
  - people skills are as important as technical skills
  - flexibility
  - willingness to try new things
  - volunteer experience – either where you want to work or somewhere else
  - Student Conservation Assocation (SCA) experience is good and there is no age limit
  - internships
  - take the state exams and find out what you need to know
- GANDA (Garcia and Associates, consulting firm)
  - flexibility increases marketability
  - diverse background
  - job applications are often seasonal, but can lead to hiring if it goes well
- Private sector
  - each firm has its own culture, figure out whether or not you will fit in
  - seasonal work is good for both sides because the employee and employer can test each other out and see if it's a good match
- Consulting
  - job ads often have a long list of what they're looking for in an applicant, but you don't always have to have it all
- State/Federal
  - applicants should have an answer for every quality listed in a job ad, even if it is minimal, do not leave any sections blank
  - a lot of experience volunteering or with internships
  - grant writing skills are important → emphasize this
  - a longer resume is better, include every detail you can, even driver's license and Microsoft Office skills
  - know people in the agency
  - it is hard to get a state job
- Forest Service
  - repeat information whenever it is appropriate, applications can get split up
- The Nature Conservancy
  - now hiring more policy experienced people
  - in the past, they hired many fresh, applied people

- skill sets are highly variable, depending on the position
- no structured checklist for applicant qualities, unlike the government
- few applicants meet all of the requirements in the job ad
- applicants should meet many or most of the requirements in a job ad
- entrepreneurship
- flexibility and willingness to learn new things
- can-do attitude

*What are some differences between Forest Service, The Nature Conservancy and consulting jobs?*

- working for the Forest Service, there is a very set schedule of duties
- working for consulting firms can be more flexible depending on the company and what the job is at that time
  - sometimes there is a lot of traveling and sometimes not
  - you have to 'chase contracts'
  - the work varies from year to year
  - there are many different opportunities within consulting and the work can change as life situations change

*Other notes*

- look for opportunities available to students that will not be available once you finish school
- a lot of people working for the state and forest service will be retiring in the next 5-10 years, so there may be a lot of job openings
- there is a hiring freeze now due to budgets
- CNPS is a resource for the state exam information
- Santa Monica Mountains has a new seasonal ranger program
- if you have parks service or land management experience, you'll often get an interview
- not getting hired doesn't mean you never will → keep trying
- SCA is a good entry way into federal and national park jobs
- Forest Service, NPS and BLM have student employment programs where students can work when they are not in school
- when a student applies for a job with NPS, the application is sent directly to the person they want to work for
- state service is not as rough as federal
- UC Davis has a new program through the ecology program
  - PhD with an emphasis on conservation and management
  - trains students for a conservation career, not academia
  - 1$^{st}$ year – three courses
  - 2$^{nd}$ year – group project one year long with an agency or non-profit
  - students do the dissertation work with an agency
  - contact Sarah Haskinson or Marit Wilkerson if interested

*Is it more important to be well rounded or have good GRE scores when applying to grad school?*

- depends on the school
- talking to the professor you want to work with is the most important
- NorCal Botanists offers a student scholarship for botany students
- the Forest Service has a big impact on the health of society by enacting change and working in many different areas
- if you have funding for a project, you can leverage it and get matching funds from other groups to get the work done

## Weed Management Contractors: Future Market and Needs

Mark Heath Leading (Contractor)

David Chang Moderating (Client)

*OK, let's just admit it; this is a confusing area for many people. An overview to clarify some basics about what is legal, required, and advisable under various scenarios will be provided, followed by a Q & A. Specific questions to be addressed: What types of contractors can legally perform weed management work? What are the benefits and disadvantages of the different types of professional licenses? How does one go about finding a contractor and how do you make sure you get the results you're paying for? How does one set up and become a successful wildland weed control contractor? Contracts – Is everything negotiable?*

This discussion took a "shotgun approach" to accommodate both clients and contractors. Most of the group seemed to be clients.

Handouts were provided detailing the types of licenses available, the types of contracts usually used, an outline of the topics for discussion, and a packet on how to develop bid specs produced by another environmental contractor

*The federal government has a large number of regulations and guidelines for putting out bids and hiring, but how should clients define their desire and outcomes in these bids?*

a. Maybe bypass results-based contracts even though results-based outcomes are generally desirable

b. Have a detailed scope of work to avoid a change order and corresponding increase in price

c. Clients may not know exactly what they want, which can be difficult for the contractor. Competing contractors may be less careful to help clients figure out what they want and end up underbidding.

*Suggested performance measures that have worked for Shelterbelt?*

a. Keep things flexible – maybe by using a Time and Materials contract with a Not-to-Exceed time and 95-98% endpoint

b. Acknowledge risk

c. Absolutes (such as eradication) are not desirable – they can end up in nasty negotiations with lawyers.

d. Share communication and knowledge, understanding of the variability involved between the two partners is best.

*When do you pay your contractor?*

a. Fixed price contracts with stepwise triggered payments

b. Invoice retention – 10% released at a given milestone. Plus endpoint payment retention

*c. All options are open!* But your terms will influence what kind of bids you get as a client.

*Writing an RFP*

a. Different levels of cost estimate will trigger different regulations for state / federal clients and change how bids are put out.

b. "Best value" is determined by the RFP, which may be written to avoid the lowest bid!

c. Liability issues influence RFP writing.

d. Amount of variability can influence a fixed price contract, so it becomes a gamble with how many bids one will get for a project. A different bid type might be better for high variability projects.

e. Have a 20% contingency for time and materials contracts. Provides a "bonus" for getting work done quickly

f. Weed world is small! Contractors don't want a bad reputation.

*What happens when the goal isn't met?*

a. Mark wasn't sure because it hasn't happened to him.

b. Go into negotiations

c. Mark recommends getting feedback throughout the project to avoid that issue

d. Shared responsibilities should be built into the contract

e. Monitoring throughout the time period is key

f. Contract specs determine who can apply

*How do you find a list of contractors to mail your request?*

a. CalIPC Proceedings

b. Word of mouth

c. Check with other agencies

d. Army Corps of Engineers made a self-reporting list with a disclaimer for wetland delineation.

e. SERCal newsletter

*Should a client pay for travel and hotel?*

a. Possibly more for out-of-the-way counties

b. Depends on how far they're going because travel increases the overhead

c. Business operations may not accommodate longer distance travel at all

d. Some contractors travel widely, some not. Some used to and failed.

e. If you like the contractor enough, it may be worth it to pay travel.

*Where do clients find business?*

a. People approach them

b. Referrals

c. Public record from past projects

d. "Via?" online – send emails on contracts available for public work.

e. The government has a list of preferred contractors they can use for a work order.
   - Simplifies process for agencies
   - Still competitive, but can be an "on-call" basis for set to be long-term contracts.

f. Contractors will work with clients to build the contract, and often prefer this course.
   - Many will help design the project pro bono because it increases their chance of getting the bid.
   - Some risk to them in doing this.
   - But clients are more likely to get the contractor they want.

g. Contractors will also help write grants because it allows for a sole-source funding situation, as opposed to general fund. Can help bypass some of these bidding regulations?

h. Can bring agricultural or forestry people in as contractors
   - May bring different skills and equipment
   - Safety standards may be very different
   - Make sure all the basic safety requirements etc. are in the contract from the beginning and understood!

i. Avoid nozzleheads with little environmental or ecological knowledge
   - Contractors! You should go advertise at WSSA (weed science society!) because there are few people in wildland or natural areas work sponsoring there.

*General suggestions and comments*

a. CA Conservation Corps has no overhead and streamlined contracting process with some agencies
   - Cal-IPC is trying to help mentor CCC to improve their weed knowledge

b. Temporary hires and prison crews are also cheap, but the work may not be of a high quality.

c. Public regulations require that some disadvantaged people must be included in public projects, and have to be hired off a list.
   - They are sent to join the contractor's crew.
   - Labor laws dictate that the employer (contractor) must train and supervise disadvantaged employees hired through this process.

d. There's a *shortage* of licensed contractors.

e. Contractors can hire subcontractors or clients can hire multiple contractors to divvy up large jobs into different specialities.

f. Ask contractors to itemize their costs if you want – big clients always will. Then you can compare contractors more directly and know which are a better fit for your needs.

g. Because weed work is time and season dependent, develop contracts with flexible plans built in.
   - A good contractor will help you write this
   - Sometimes less skilled contractors are easier to accommodate

## Weed Control: Riparian Weeds Working Group Notes

Leader: Mark Newhouser, Sonoma Ecology Center
Facilitator: Gretchen Coffman, WRA Environmental Consultants

Note Taker: Kai Palenscar, UC Riverside/Cal-IPC Student Chapter

Number Attending: 24

*Explore the mysteries of riparian weed control as we delve into the murky world somewhere between the terrestrial and aquatic. Discussion will include weed control challenges, new techniques and successful combinations, tricks of the trade and traps to avoid. Group participants are encouraged to prepare questions or scenarios and at least one gold nugget of advice to share. Rewards for best technique, worst scenario, best question, and best advice.*

Mark Newhouser started off the group with brief introductions and sent around a sign in sheet. Introductions lasted 10 minutes.

Invasive species of interest included: giant reed (*Arundo donax*), broom species (*Spartium junceum, Genista monspessulana, Ulex europaeus*), plum (*Prunus* sp.), mock orange (*Pittosporum undulatum*), tamarisk (*Tamarix* spp.), and white sweet clover (*Melilotus alba*).

*What is the best method of removal of one acre of calla lily (*Zantedeschia aethiopica*) along the creek within a riparian community?*

Location: Santa Cruz – Soquel Creek

- Tried and failed with hand removal but bulblets were not successfully removed.
- In agricultural systems fumigation is used to kill previous year's crop of lilies.
  - This technique is not feasible along the creek.
- Check to the Presidio in San Francisco and other infestations of calla lilies along the coast to see if anyone has had success with removal.
- Example of other bulbiferous species
  - Arrowhead have been treated with glyphosate (Roundup)
    - Late season treatments tend to show regrowth from bulblets
    - Early season treatment may show better kill rates and may be effective on callalillies.

**Cautionary note – DIGGING/MOVING TO REMOVE PLANTS JUST TRANSLOCATES BULBLETS TO NEW LOCATION**

- Grazing? Are wild boars an option?
- Water table depth = 10 feet
- Pasteur management - Missouri iris (*Iris missouriensis*) is treated (glyphosate - Roundup) when flowering, as his is the time of maximal herbicide translocation. Usually one treatment is enough to achieve a full kill. Treatment is by weed wipe application of Roundup.
  - Weed Wipe – foliar application of foaming herbicide from a roller device.

*How can leafy spurge be treated during early infestation when it is found within the riparian community? Access is difficult.*

Location: Siskiyou County, Klamath River – recent invasion of dalmation toadflax (*Linaria dalmatica*) and leafy spurge (*Euphorbia esula*)

- Is biocontrol an option?
  - Spurge population may not be large enough.
- Basic biology is important for control options. When is its most vulnerable moment? Dispersal is by seed.
- Kayaks or boats may be a viable option for access.
- GIS – has not mapped the problem areas associated with this question.
- Example – Montana and Idaho
  - Biocontrol (beetle) has been very effective on leaf spurge.
  - Does not eliminate all plants but keeps current populations from expanding.

- Beetles have been released into California and Oregon
- Check with USDA for more biocontrol options
- Ensure local Agricultural commissioner knows of infestations
- Toadflax – still available within wildflower mixes in Sonoma County as an ornamental. Likely to be an ongoing problem

*How to best remove Arundo from within hard-to-access riparian areas?*

Location: Santa Clara River, CA

- Can you move cut *Arundo* stems to local sandbar for later burning?
- Agencies do not allow stems to be left on site as they can re-grow and are problematic during flooding.
- Work can occur between September 15 and March 15. Work during the rest of the year may negatively affect breeding or nesting activities of threatened/ endangered bird species (Bell's vireo, southern willow flycatcher)
- Burning permits (from CDFG, watershed protection district) are necessary to burn *Arundo*. Strict guidelines on when, how and where you can burn
- It is easiest to treat (foliar herbicide treatment) and leave stems in place.
- Location is adjacent to a nature preserve.
- Size – 18 acres with approx. 6 percent cover of Arundo.
- Fire is a problem in this area and likely to spread.
- Can you float stems downstream?

  Not an option. Too little water.
- It is most typical to kill in place and then to cut and transport stems off site or chip in place.
  - Southern California procedure
  - Spray
  - Leave in place for 3-4 months
  - Grind in place with a flail mower or some other chipping method
- Jason Giessow recommends to never cut *Arundo* stems prior to herbicide treatment. It re-grows and herbicide translocation is minimized to rhizome.
- Cut-paint application method is very successful but you still have biomass problem. This method is costly and time consuming.
- Cut stems left in watershed have led to infrastructure damage during flooding. Example – school damage that led to the county (which?) being sued for damage
- Burning stems alleviates this problem but permits are necessary and agencies force you to clean up ash debris.
- Bend and spray technique
  - Alleviates biomass problem
  - Lessens the concern over fire and flooding damage
  - By bending stems the nodes snap/fracture but the phloem vessels (internodes) are not fractured allowing herbicide translocation to the rhizome
  - Stems over ¾ in. diameter are too lignified to use this method.
  - Procedure lays stems (direction = downstream) to the ground in a fan and then each successive layer is sprayed with glyphosate (three percent Roundup solution). Bent stems stay bent to the ground to lessen fire danger.
  - Tools – hook and/or ladder to gather stems to the ground
- Jason's wife has shown that it takes at least six weeks of drying to completely kill *Arundo* stems.
- Burning – burn days vary by location
- Float-a-pump – pumps water from a body of water so as to provide water to put out local fire. Can be used when burning *Arundo* stems. Also great for wetting native vegetation to keep from burning.
- Fire can be used as a training exercise for local firefighters.
- Surfactant necessary to stick herbicide to Arundo leaves
- Mentioned – Agro Dex, R-11
- Imazapyr – Zorro Stroke, if used it does not need high percent foliar coverage
- Helicopter Method – Use helicopter to airlift stems out of the riparian zone.

*How do I get the County to control its invasive species problem in a county park?*

Location: Kern River

- The county park has a reservoir with an island. *Arundo* is on the island and water hyacinth is in the reservoir.
- Water recharge to the reservoir and river system spreads invasive.
- Local residents have treated plants with illegal spraying for free.
- The city (?) will charge $786,000 to remove.
- What is the best method or action to solve this county problem?
  - Report the problem to the county

*Awards*

- Six awards were given out to various participants.
- Grand Prize recipient – Dale Schmidt (LADWP)

## Weed Control Q&A: Brooms and Other Woody Invasives

**Leader:** Janet Klein, Marin Municipal Water District

**Facilitator:** Carla Bossard, St. Mary's College of California

Note taker: Lynn Wihbey Sweet, UC Riverside

*In February of this year, 45 broom managers from around the state gathered for a raucous discussion of the good, the bad, and the ugly in broom control. Join us as we move the conversation beyond tools to the more complex issue of achieving sustainable control on a landscape scale. Summary information from the February meeting will be distributed and discussed.*

### Introduction:

Janet –

This is a follow-up from the February meeting about broom species. Several experts attended the last meeting. The meeting was written up for treatment and specific advice from and for land managers. This is being put together currently, but is not done yet.

Help is needed with tables, comments, and especially costs. Currently listed costs are estimates and are likely not correct. This needs to be refined before it goes up on the website.

Today's workshop is not for nitty-gritty of each technique, but about choosing techniques for different situations. WHEN to use management tools.

Break-out Groups: three Scenarios

Fuel Breaks
Restoration
Seedlings

### Results from Break-out Group Discussions (whole-group discussion):

***Fuel Break Scenario:*** *Ridge-top fuel break on the roadside, a 200 foot wide swath that has type-converted. In the 90's this was just mowed.*

- Break-out group notes
  - This is similar to roadside and logging sites.
  - Hand removal is possible at small scales.
  - Herbicides work great and minimize soil disturbance.
  - Mowing can reduce fuel loads, but not long-term costs.
  - Timed mowing can reduce seed set.
- Mowing the area- it won't kill it but will be a permanent annual task. There is still seed production here.
- There might be a window to spray. Mow in late spring, then two months later, 2% glyphosate foliar application, three years in a row. First and second year the effort is high but the third year costs are much lower. By the third year, you can keep it from setting seed.
- Do you need to get it out in this case?

- Cost projection of annual mowing is very high. Landscape management is preferable, will drive down permanent maintenance costs.

- Mow then tarp?
  - No, not 40 acres. This is too large. 1/3 acre was difficult. Less than one acre hand removal or tarping may be viable tools.
- If you can't get herbicides there, then hand-pull. This is more expensive though.
- Mulching?
  - Issue of scale again- this is too big an area. A 1980's experiment showed that 8" of mulch failed and it is still coming back.
- Many site-dependent aspects to managing this scenario.

***Restoration Scenario:*** *100 acres with valuable plants and part of the area is a watershed area that feeds a municipal drinking water source.*

- Break-out group notes
  - Survey for special status natives
  - Seedbank test (and viability)
  - Ten-year strategy:

    Herbicide: 50 acres NOT draining to reservoir

    Hand-pull: Sites of exceptional value

    Goat grazing: On NON-herbicide, NON-special status sites

    Torch: Seedlings and resprouts where appropriate
- Survey the area for special status natives. A seedbank viability study wouldn't take long.
- Look at a ten-year strategy, and work with the part without the watershed first.
- What about burning?
  - No, this would impact the oak woodlands. Around the plants of exceptional value, hand-pull.
- Ten-year strategy could involve goats. The first year they would chew it back and then you could hand-pull your way in. Flame the seedlings to prevent reestablishment.
- Janet - Likes the partitioned method. Unfortunately, goats like madrone; the trees would have to be protected. You could hand-pull post-goat, but the result of herbivory would be that the root mass would be expanded and harder to hand-pull.
- After using a "holding-pattern" of mowing, you have 100 acres of 20-year old stumps too.
- Janet – Cut-stump herbicide treatments good of land management agency policy allows for it in water-supply watersheds. Toxicology studies show risks to drinking water can be mitigated with timing, buffer-zones, selection of least toxic herbicides.
- All-in-all the goals of the first two scenarios are different. With the fuel break scenario, you can mow, and the goal isn't restoration. With the restoration scenario, you can't live with the broom and it must go. In the restoration scenario as well, you are concerned with ecosystem-level changes due to invasion, such as nitrogen fixation by broom.
- Goats for broom control?
  - Janet – They will eat broom when there's nothing else, but they will wander to other plants, so you'd need to manage them intensively. They won't kill the broom.
- Goats may bring in weeds, so it's important to request weed-free goats-that have been cleaned, and fed weed-free food.
- Sometimes the place and site are too difficult to get to, and you can't justify the use of time-intensive methods, such as hand-pulling.
- If there are endangered plants here, you have to restore this area. How about using a highly-competitive native?
  - Yes, but not many species can out-compete broom and if it does, do you really want it there?
  - There is too little data on this topic, and you may get a new problem.
- Big areas, you can mow in perpetuity. Also you could have one final burn to kill off the stumps; a very intense fire and then use other resources to follow-up.
- Also you could change the way you burn – pretreat, or burn in a different season

- Janet – Sometimes in these areas, you're lucky to pull off a burn at all due to winds, fuel loads, proximity To urban areas, etc.

***Managing Seedlings:*** *100 acre site where the adult stand has been removed by pulling or burning. Site now supports 1,000,000 new seedlings.*

- Suggestions from the break-out group: 1) Flame the seedlings if possible, although this can be iffy if there is not enough moisture. 2) Spray them. 3) Pull them
- Carla – We're conducting a pilot study on using a chemical from *Synopsis alba* seed pressings. It's a chemical compound that is effective on things in that family- broom. We're using three levels of dosage, and may need to up the dosage. Don't have conclusive resultsyet, but so far, we have a drop of 80-90% in the worst sites. We're going for 100%.
- Do you need a license for this?
  - Carla – No it's experimental, and we're working with the University of Montana. They've looked at the effect on the soil profile and biota, and they've shown no negative effects with respect to soil community.
- Suggestion: Using Ascetic acid, 15-20%. This works on seedlings, just above the cotyledon (once plants have first true leaves), but chemical burns to applicator a problem.
- Suggestion: Matran, which is concentrated eugenol, or clove oil. The carcinogen is removed. Achieves 99% kill when applied at high rates, but it is very costly.
- Suggestion: 5% strength Scythe or Peloric acid. It has a very short half-life. This could be used, for example, when you've planned to flame, and missed the window of opportunity to use a flaming method. There have been some limited trials on this in two sites, and results will be presented next year at the conference. Maybe someone else could do trials too? This won't work on Scotch or Spanish broom, only on French broom, when young. This species is more like an herbaceous species at early stages than the other two species, which tend to become woody more quickly. Using this on re-sprouting stumps is not effective.
- In general, with broom, can we pull in August and September? Using a weed wrench?
  - Janet – Timing is relevant. If you do it in winter, it's more effective. If you can pull in summer, it's slower, and there is no change in germination next year (seeds have dropped). One idea is to pull in August, then flame in December. That way you get two cohorts.
- Also, the firmness of the soil may affect your success and will vary with the time-of-year.
- If you just cut the broom, you aren't disturbing the soil, and then the reserves won't be there in the spring.
- The broom has to be near senescence for that to work.
- Treatments therefore will be site-dependent.
- There was a poster at the meeting about using a high pressure water treatment to get rid of seedlings. How would that affect the soil?
  - Janet – It works with these seedlings. It's a high-pressure wash at about 1400 psi. It does disturb the soil. This method could be used, for example, for tall fescue or pampas grass. It's pretty incredible for getting out root balls. This method is not suggested for mature broom, however. You'd basically make a bunch of muddy ground and then have to hand-pull out the root mass anyway.
  - A lot of water would be used. On 1/3 acre in two days, 600 gallons of water was used. This method remains promising, though.
  - Keep in mind that this is a technology that a vendor is selling. This is probably most effective on seedlings.
- Are you just going to churn up lots of mud and spray it everywhere?
  - No, you can shave these off at the soil line. This method has become much more precise. It's worth watching in the future.
- Carla – Are you going to lose soil? Is it possible not to?

- Janet – This often depends on the operator. It's very precise in this case and is much improved.

- What about on unstable slopes?
  - Janet – Spray if you can. On a cliff-face, try to cut it down, then use herbicide.
  - Ken – Leave broom and kill them on steep slopes. Removing them entirely can lead to serious erosion, so leave the roots.

- And then use revegetation to speed the recovery?
  - Janet – Watch the seedbank, and see what comes up, to see what you have there. Don't re-vegetate too soon.

## Weed Control Q&A: Upland Invaders

Leader: Joe DiTomaso

Facilitator: Tanya Meyer

Notetaker: Sara Jo Dickens

*Leaders will summarize new and innovative control news, focusing on thistles and knapweeds (including yellow starthistle), and then field questions. Two of California's experts will discuss some of the new techniques for weed control and where they best fit, as well as their limitations. Participants are encouraged to discuss their current difficult weed problems. Group leaders and other experts in the audience will try to come up with some best management options.*

Discussion began with an introduction from Joe:

- Dupont has a new product called KJ44 that is not out yet, but Joe has been doing some testing of the product. It has a three month soil residual, works like milestone and lower toxicity than milstone (low risk). It is an auxin like herbicide with a different spectrum than milestone and may work better on shrubs. Milestone has been out for two years and has a two month soil residual. It has been seen to be three times more effective on yellow star thistle than transline and good for control of knapweeds and tuff forbs. To treat the same species, other states are using Tordon and Picloram, but these chemicals are not labeled for California and have a two-year soil residual (have been found in ground water).
- CDFA is working with Joe on Dalmatian toadflax (*Linaria dalmatica*). There is a biocontrol that has been successful in other states that is being introduced to Hungry Valley, California. CDFA has been successful at keeping Dalmatian toadflax down and hopes this new tool will prove even more successful. The biocontrol is very host specific and thus may not work on the related species, Yellow Toadflax (*Linaria vulgaris*).
- Yellowflag iris (*Iris pseudacorus*) is becoming a problem in wetland areas (Jasper Ridge, Sonoma Co.). It is an ornamental plant that has begun to escape. Joe is working with JP Marie at the Putah Creek Preserve to determine a control. Currently they are using Habitat and finding good results. Monsanto has been using an injection system which is working.
- *Diorhabda elongate* beetle is continuing to be successful in Nevada on controlling tamarisk and there is a plan to introduce it into Cache Creek in California. The beetles introduced will be collected from an area with similar habitat to Cash Creek. The beetle is thought to prefer *T. ramosissima* and *parviflora* spp. Where it has been released, *T. parviflora* is being cut back significantly, so it is hopeful that it will also have the same level of effect on the *T. ramosissima* Cache Creek.
- **Ravennagrass** (*Saccharum ravennae*) is a problem at Cache Creek (along with Arundo) for which efforts are being made to remove it. The method that appears to work is defoliation every year for five years. In areas where this method is working, monitoring is in place to observe what will replace the **Ravennagrass**. It is advised that once the **Ravennagrass** is dead, removal of the dead bodies would likely cause unnecessary disturbance. These dead bodies also provide bank stabilization until other species are able to reinvade.
- Journal Release: "Invasive Plant Science and Management"
  - 75% of the articles are from the west. This is likely because of our high level of invasives.
  - Includes invasive alerts in the journal important to California.
  - If you subscribe, you can get the back issues. To get particular articles, Joe can be contacted by email to get a PDF.

**Participant questions and comments:**

Spotted knapweed *(Centaurea maculosa)*_ Treatment with milestone for one year will kill the plants, but the seed bank will require repeat treatments. Small patches can be controlled by hand pulling.

**Dalmatian toadflax (***Linaria dalmatica)*_ Dip and clip method works well. Dip the clippers in herbicide and then clip with them. The method is similar to the cut and brush/paint method used on more woody species.

*Brachipodium distans* If you can't use fire to treat due to regulations or nearby housing and mowing has not worked, there are a few options. 1) Grazing with sheep, cattle, or goats. 2) Change the timing of the mowing because the window for effective mowing is short. If mowing didn't work before, it may be that the window was missed and not that the method doesn't work. 3) Try an organic herbicide. 4) Steaming of the plants with high temp and pressure. There is a company that does it for $10,000 per visit, but this often has to be repeated three or more time.

**Common teasel** (*Dipsacus fullonum*) In an area that has many rare natives that prevent the use of grazing for control, it might be worth looking into a biocontrol used in the prairie states. Hand digging appears to work for small patches. If you are dealing with Fuller's Teasel (*D. sativus*), you can pour herbicide into the cups of the leaves, but Common Teasel leaves do not have the cupping. The use of mowing for a few years can kill the adult plants and rosettes can then be killed with one year's worth of spraying with Roundup. Teasel is a biennial but in Marin County it appears to be acting as a perennial. It may also act more like a perennial if you chop the heads and leaves, but leave the roots intact. It has been observed in adjacent fields that those with grazing have fewer or no Teasel compared to those ungrazed. But others have noticed the opposite, which may be a response of the Teasel to the disturbance of the grazers or may be a result of poorly timed grazing. It is agreed that the grazers do in fact eat the plant and cattle are the best option.

**Medusa Head** (*Euphorbia flanaganii)* Spray it with molasses to lure the cattle in to eat it. This will work in small patches to make the plant attractive and helps keep the cattle selecting for the weed and not the natives. Other options include mowing, flaming, burning in the winter and covering with a tarp. Unfortunately the seed bank life of Medusa Head is about two years. It is not a good competitor, but its silica-based thatch seems to aid in its persistence. A mowing procedure that has the potential of reducing cover by 99% is to mow then rake out the thatch. The raking exposes the seeds at ground level making them susceptible to burning. Roundup early on is useful in solid patches, but will kill natives too. The herbicide Matrix can now be used in California and has proven effective on Medusa head. A paper from the UC Davis Extension by Rob Wilson tested many chemical treatments and provides the effectiveness on many plant including Medusa Head. The herbicide Plateau is effective but not yet labeled for California (has been used in sage brush with less damage to sage brush than other herbicides).

**Canada thistle** *(Cirsium arvense)* It is considered a northern state weed where it spreads quickly, but in the south it might stay small. To control it you can mow just before it goes to flower and repeat this until it depletes the root's resources. Milstone also works.

**Bermuda grass** *(Cynodon dactylon)* If you can't use herbicide because you are near a riparian area, black plastic covering in July and August can kill it. A good resource for more options is wrc.ucdavis.edu Pest Notes web page.

*Senecio silestrus and S. jacobia* The species has been seen to move in like bull thistle and since it has wind-blown seed, may become a serious problem. It is filling in after fires and persisting. There is a biocontrol, longitorsis beetle and the Cinnabar moth, but matching climate of insects to the host site will be important. A Dow chemical called Vista is also working. It is a non-agricultural registered herbicide with a 24-hour soil residual.

*Dittrichia graveolens* It was seen first in Santa Clara County along roadsides and now on the shores of a reservoir where the waterline recedes. It appears capable of growing in wet soils. It moves into the wet areas as they dry down. It can come up anywhere there has been disturbance. It is a summer, late season annual. Low mowing preflowering can work with follow up mowing. It has shallow but many roots, which leave it unclear as to where it is getting its water. It is advised that handlers use gloves as 50% of people will get dermatitis (allergy leading to blisters) in one to two days after contact.

**Fennel** (*Foeniculum vulgare*) It is mixing in with natives making it hard to control. Manual removal is effective, but the patches are often too large to do this and the disturbance of pulling might stimulate more seeds to germinate. Suggested that interested parties contact Jennifer Erskine who focused her PhD on Fennel control on Catalina Island. Jessie Elger has been using an herbicide backpack sprayer with Roundup, Garlon or Imazapyr in wildlands.

**Tumble weed** (*Salsola tragus*) Can cause Sabra dermatitis an irritation caused by many plants. It is the result of small hairs or spines getting under the skin and irritating it for several days. It is not due to a chemical.

**Poison Oak** (*Toxicodendron divers-lobum*) Oils may increase in strength with increased $CO_2$ predicted with global change. Lou Ziska is conducting research on this.

**English Ivy** (*Hedera helix*) it can be an allergen.

**Goat Grass** (*Aegilops triuncialis*) Control has been accomplished with Envoy, a grass specific herbicide that kills all grasses but fescue. Hand pulling takes ten years to get control. Mowing shows mixed results due to the difficulty of timing. Seeds can finish developing after mowing, so clippings may need to be removed. Hydro-mechanical obliteration, which is like a pressure washer with water has been used, but causes a lot of disturbance to loamy soils. It may work better on hard-packed clay. The user can control the impact by adjusting pressure enough to hit annuals and not the natives.

**Onion Weed** (*Nothoscordum gracile*) An infestation has been found in Santa Barbara. Carl Bell at UC San Diego is a good contact for control information. Zelar has been seen to work, but it can not be used in riparian areas. The root of the plant is six inches long. Rabbit grazing seems to reduce it so mowing may be effective.

**Purple Star Thistle** (*Centaurea calcitrapa*) In areas where mowing is not an option, Milestone can work. The revegitation process will likely be difficult in rock-hard soils.

Kikuyu Grass (*Pennicetum clandestinum*) Herbicides that may be useful include: Roundup, Rodeo (if near water), and Tricloper. The managers of Torre Pines Golf Course have been dealing with it successfully for awhile, so it may be worth checking in with them. The Pest notes page of UC Davis Extension has further information as well.

**Crimson fountain gras**s (*Pennisetum setaceum*) Check with Dr. Jodie Holt's lab for information.

**Perennial Pepperweed** (*Lepidium latifolium L*) Roundup didn't do anything. After mowing 10% resprouts and 90% of those produced basal leaves and then spraying Roundup on these remaining plants works well. Without mowing first, the Roundup will not reach the roots and thus will not be very effective.

**Hedge Parsley** (*Torilis arvensis*) Transline will not work, but Roundup and Garlon have been effective for control. Scott Onetio at UC Davis is currently focusing on this spp. for his Master's thesis, so he may be a good contact.

### General Chemical information

- Clefadim works for grasses
- Roundup is the most used herbicide. If you are trying to control ten different spp. and don't want to change the chemical in the backpack sprayer, Roundup is the chemical to use, but it will kill everything.
- Milestone can be used as a pre-emergence treatment for grasses.

- R11 surfactants are more toxic than thought; Competitor might be a safer alternative. When Competitor is mixed in Trichloper it has been seen to impact non-target grass spp.
- Milestone works on Curly Dock and Picrus, bur will affect Amsinkia spp. This impact on Amsinkia can be reduced when treating Yellow Star Thistle in March.

**Other noteworthy reports:**

- The chemical extracted from knapweed (Catkin) that was intended to be used to make a natural herbicide was not the chemical the researchers thought it was. Due to this set back this project has been put on hold.
- Joe announced a project for which seven people will be collecting weed control information for non-crop invasions. It will be a Non-crop Weed Control Handbook for 300 spp. including information on control. The information will not be site specific so managers will have to consider the characteristics of their sites before applying the handbook information. The projected completion date is one year with a revision/update every two to three years.
- A common issue is finding plant species to stabilize banks and slopes after weed removal and disturbances such as road building. Salt grass was recommended, but the seed production is often not very successful. The use of Salt Grass plug may be more effective. Ripping of the soil prior to planting will help with establishment. The other recommendation is Barbasilus, but this species needs a good deal of water. It was agreed that we need to educate agencies on how to use natives more often.

## Future Research Needs for Invasive Plants)

Discussion leader: Mona Robison, California Botany and UC Davis

Note taker: Heather Schneider, UC Riverside/Cal-IPC Student Chapter

*Help set the research agenda for invasive plant management in California! Cal-IPC recently prepared a draft of invasive plant research needs for California. We will briefly review the findings and ask for input from workshop participants. The ten research needs areas covered were: Biology and Ecology; Distribution, Biogeography and Range Modeling; Ecological Impacts; Control and Management Methods; Restoration; Human Activities Affecting Invasion; Economic Impacts; Social Issues; Risk Assessment; and Policy and Laws. We will also discuss research funding opportunities.*

*A series of posters were put on the walls with research categories and corresponding issues written on them. After a brief discussion, attendees were encouraged to add to the posters and rank the importance of the issues using stickers. High numbers of stickers indicates high priority. The posters and priority rankings were discussed after everyone had contributed their comments and stickers to the posters.*

### Preliminary Discussion: What are the research needs priorities?

*How can managers get access to peer-reviewed journals?*

- The National Parks Service has JSTOR access
  - The most robust way is through a university library or research institute
  - Managers can get an 'associate in the experiment station' or other courtesy title and have library access
  - Make contacts and the university and find a way to loosely associate
  - Courtesy appointments are easy and free to obtain, if one person can get a courtesy title then everyone can have access
- Yosemite and UC Merced have an established relationship, so some people have access to journal articles
- NPS can request articles, but it can be tedious
- Do journals allow Cal-IPC to post abstracts? (This material is typically copyrighted)

*Assessing the research needs document and poster topics*

- Some people mixed up exotic and invasive plants
- comment by Jodie Holt
  - We can't encourage students to do unpublishable research, some of these needs are things Cal-IPC should hire and pay people to do
- Response by Ted Grosholz
  - Science and management need to come together to be effective
- Is our definition of research too broad?
  - Some areas are addressable, others no one wants to work on and are not publishable

*What do the stickers added to the posters mean?*

- Prioritization
- Start broad and then narrow/define it
- There is a need for a second filter after the interviews for the research needs assessment: academic vs. policy

  i.e. CDFA California aquatic invasive species plan
- The dots should be placed on what is important and then decide what is good for who
  - This is how the state weed plan was developed and there is overlap with this
- A subcommittee should decide on the top ten priorities and then decide what is fundable

The total project timeline is to finalize a draft at the end of the year and post it on the Cal-IPC website

#### *Poster #1: Biology & Ecology 22 dot stickers total*

- Synthesis of biology and ecology information (7 dots)

- Seed biology and seed bank dynamics (5 dots)
- Below-ground research (4 dots)
- Genetics and molecular tools – use in taxonomy (3 dots)
- What research is publishable/fundable? (0 dots)
- Application of genetic methods to identify invasive populations, genotypes, cultivars, and hybrids (3 dots)
- Access to scientific literature

**Discussion:**

- What does a synthesis of information mean?
  - A lot of people mentioned this in the interviews
  - How can we find and put all of this information into one place?
- How would a synthesis of biological and ecological information be funded?
  - Use the Local Flora of the British Isles as a model?
- There is limited interest and funding to use genetics for identifying invasive populations, genotypes, cultivars, and hybrids
  - The general public does not always realize how much work goes into genetic techniques
- There are a lot of questions about horticultural plants

### *Poster #2: Ecological Impacts – 39 dot stickers total*

- General ecological impacts (9 dots)
- Gather and synthesize data on ecological impacts (12 dots)
- What are acceptable thresholds for invasives? (4 dots)
- Interactions of wildlife and invasive plants (5 dots)
- Which native plants persist in invaded areas? (1 dot)
- How do ecological impacts vary regionally and among communities? (1 dot)
- How do ecological impacts vary with time and space? (1 dot)
- Establish permanent plots to track invasions (4 dots)

**Discussion:**

- Acceptable thresholds for invasives is also a social issue
- Impacts need to be evaluated at each threshold
- What are the impacts of different levels of invasion at each location?
- These points have been the basis of weed science for hundreds of years
- It is never economically viable to eradicate weeds in agriculture; it is not sustainable
  - There is a difference between economic and ecological thresholds
  - Control is maintaining a level of weeds without them becoming a problem → but a problem for whom?

### *Poster #3: Distribution, Biogeography, & Modeling – 18 dot stickers total*

- General distribution, biogeography, and modeling (3 dots)
- Statewide weed maps (7 dots)
- Easy modeling for land managers (1 dot)
- Collect data to run models (1 dot)
- What are yearly cycles of invasions? (1 dot)
- Time to reproduction for rate of spread
- Resistant habitats (4 dots)
- "One-click" data aggregation for updating (1 dot)

**Discussion:**

- Develop standardized data methods for sharing
- Modeling for managers
  - Not practical for small land areas

    By the time the model was validated, it would be a challenge to use it
  - Climex is not an easy model and it's expensive
  - Gina's prioritization model in Excel is easier to use
  - Someone else could use the model and hand the info over to managers
- Collect data to run models
- Which plants are coming in?
- Which species should we worry about?
- Once a weed map is created, it's already out of date → they require constant updating

### *Poster #4: Risk Assessment – 27 dot stickers total*

- Detection and screening at borders (2 dots)
- Pathways of entry (5 dots)
- Predicting which spread after introduction (2 dots)
- List of plants already introduced with dates (0 dots)
- Evaluate horticulture plants for invasiveness (6 dots)
- Which cultivars are invading? (4 dots)
- Evaluate “alternatives to invasives” and changed promoted natives for “genetic pollution” risks (3 dots)

**Discussion:**

- Look at Consortia of California Herbaria for introduction dates
- Determine which species come in through certain pathways?
- There is not much literature on weeds along transmission corridors → more research needed?
- Some pathways of entry are obvious to us but not well documented in the literature

### *Poster #5: Human Pathways & Prevention – 19 dot stickers total*

- General human pathways and prevention (2 dots)
- Which plants move along roads, railroads, levees, and utility corridors (5 dots)
- Nitrogen deposition and serpentine grasslands or desert (2 dots)
- How to change land management under climate change? (4 dots)
- Fire fuel management in grassland, chaparral, coastal sage scrub (2 dots)
- Periodic disturbance – post fire/ forest harvest (2 dots)
- Citizen monitoring/early detection and prevention
- Levee management/BMPS/how maintenance is done (2 dots)

**Discussion:**

- A lot of management assumes that it is moving towards restoration, but it may be more actively managed
- Why wasn’t disturbance mentioned sooner?
- With levees, some management may encourage invasives

### *Poster #6: Control & Management – 22 dot stickers*

- Compile herbicide impact information (1 dot)
- Which native plants are not killed by herbicides? (0 dots)
- Techniques to facilitate timed high intensity grazing (2 dots)
- Seed bank depletion for eradication (5 dots)
- Secondary effects of control methods (1 dot)
- Replace ecological process with management process (1 dot)
- Managing for acceptable thresholds of invasives (3 dots)
- State/region-wide standards for monitoring treatment methods to generate comparable data sets (7 dots)
- Inexpensive control options in sensitive habitats (1 dot)

**Discussion:**

- This category had a lot of comments, but few dots
- Must realize eradication is not feasible
- Standardization is important
- Quick and easy monitoring is important for managers
- In Australia, the weed search tool estimates the cost of eradication
- Depleting the seed bank to facilitate eradication would be feasible in a very small number of places

### *Poster #7: Restoration – 25 dot stickers total*

- General restoration (5 dots)
- What combinations of plants will persist? (2 dots)
- Maximize success of passive restoration (9 dots)
- Easy ways to do effectiveness monitoring (4 dots)
- Soil restoration studies (4 dots)
- Do expected/desirable plant communities return after eradication/ treatment? (1 dot)

**Discussion:**

- There are some general assumptions in the document about restoration that may or may not be accurate
- Surcal may be able to help with maximizing the success of passive restoration
- Removing invasives is a type of restoration – restoration groups are now realizing this
- If a contractor is hired to do management, who monitors it's success and progress?
- How can monitoring be made easier?
- Restorationists should also be aware of wildlife or other goals before designing a project
- Social issue: use different language, i.e. "Restoration" not "killing"

### *Poster #8: Economic Impacts – 44 dot stickers*

- General economic impacts (23 dots)
- Quantifying economic impacts of invasives (11 dots)
- Ecosystem service costs (8 dots)
- Scale up project from single plant → large area (1 dot)
- Cost/benefit and funding sources for an invasive species rapid response fund – also social & policy issue (1 dot)
- Thresholds based on economics (0 dots)

**Discussion:**

- Surprising emphasis on this
- Need to focus on this more, get collaborators and foster partnerships
- Outreach to economists!
- Always need cost/benefit analyses for control – need to multiply this by the spread rate
- Value ecosystem services and include non-market valuation
- How do we get money and use it efficiently?

### *Poster #9: Social Issues – 23 dot stickers total*

- General social issues (3 dots)
- Psychology of what to protect/when to manage (4 dots)
- Use larger community to develop projects (2 dots)
- Develop effective messages for weed work (4 dots)
- How do different communities decide to use/not use herbicide? (4 dots)
- Work on local politics to get projects done (1 dot)
- Perceptions of invasive plants (positive/negative) by local communities (5 dots)
- Weed resistant human communities (0 dots)
- Synthesis of information for the public (0 dots)
- Decision support (0 dots)

**Discussion:**

- There is a need to educate the public and synthesize information for the public (i.e. Jared Diamond)
- There is a need to convince the public that ecosystem services are important
- This priority may not be as high because we don't understand social science → we need more social scientists to help us
- Education is a policy issue, too
- We need more research on herbicide decisions
- How does our message affect communities?
- We need to understand emotional connections to plants within communities and among individuals
- There is a need to educate the public about invasive species and ecology

### *Poster #10: Policy & Laws – 17 dot stickers total*

- General policy and law issues (5 dots)
- CA invasive species advisory council (3 dots)
- Evaluate CDFA noxious weed list (2 dots)
- Evaluate WMA program (2 dots)
- Voluntary industry self-regulation vs. government regulation (5 dots)
- How to work on weed issues that cross WMA/state boundaries (0 dots)

**Discussion:**

- WMA programs should be compared between states, etc.
- How does science get into policy and decision-making?
- Need to collaborate
- Most scientists don't want to be in politics
- This is not research, it is providing information to make decisions

**Wrap-up:**

- There is a gap that needs to be filled by social scientists and economists
- People understand money and economists can help put ecological issues into those terms
- There needs to be some bridge between science and policy makers

## Ensuring Successful Wed Control: Planning and Monitoring

Leader: Susan Hubbard, Bureau of Land Management

*Controlling invasive plants obviously involves time in the field actually removing weeds. But what else is necessary to have a successful program to control invasive plants? This workshop will focus on planning and monitoring – the things you need to do before and after weed removal. We will look at some of the basic concepts that will prevent you from making time consuming and costly mistakes and suggest how to develop a plan to ensure that you are being the most effective you can be. And we will look at monitoring and making sure we can document our successes (and learn from our failures). After covering the basics we will open up the discussion to see what has worked and not worked for those present and together answer questions.*

**Introductions**

*Planning*

- Ask should a project be done at all?
  - Consider timeline and commitment level
  - Is your organization committed?
- Prioritizing and mapping help at this stage
- Are you actually trying to eradicate?
  - Can also eliminate – local eradication but expect weed to return at some future point.
  - No net expansion as a goal? May be a good interim goal until realistic goal or agreement is reached.
- Consider the users and decide on an appropriate restoration plan.

*Organization*

- Build the program with transition to other project leaders in mind so that a project can be successfully handed off later.
  - Be Organized
  - Back up all records. Digital and hard copies!
- Consider what needs you will have to meet
  - Defend funding?
  - Research?
  - Reports – formats and questions required to answer
  - Plan data collection around reporting and organization needs
- Database!
  - Searchable records and summaries
  - MS Access-based databases are fine and can be used with GIS etc.
  - GeoWeed
  - WIMS
    - Program was WIMS first and became Geoweed laster with further development
    - Lets you tie GIS polygons with database information
    - Programs still have some bugs!
    - Can work better with pricey Trimble units than with handheld GPS units because you can download the Access database to the Trimble.

- However, Garmins etc. can get a better satellite signal and you can always enter the data later to link the geodata.
- Another benefit to handhelds is that you can buy different chips and get one that suits you
- Best – Bluetooth is available! Cannot do that with a Trimble.
- MTK makes good chips but technology changes rapidly
- Platform compatability, updates, and tech support are major considerations when building geodata because they represent an investment of time and money.

- Plan to have tech support from your company of choice throughout your project, not just for training

■ Mapping
- Don't collect more data than you need
- Collect data to answer your questions and spend the rest of your effort on the project itself
- Mapping is critical for an efficient and effective project

■ Paper Trails
- Trip reports after management each day creates continuity
- Digital and paper

■ Photo Monitoring
- Can help show change over time
- Established photo points make photo monitoring more effective.
    - Try to have a unique landscape feature in any photo point to help you come back to it later
    - Include orientation
    - Include GPS location
- Keep a consistent labeling scheme with both date AND location for all pictures and files
- Date can be autostamped by digital cameras. Just make sure your camera has the correct date set!
- Take pictures with the unexpected in mind – you won't know what's useful until later!
    - Imagine bigger implications of your photos
    - Can help defend land management decisions!
- Helps motivate volunteers to see before/after photos.

■ Data Collection During Project
- Weed counts can help you gain an idea of the scale of your project.
    - Ballpark figures are fine for most purposes.
    - Counts can be useful for publicity, fundraising, volunteer morale, illustrates effectiveness of the project.
    - Can be burdensome if too detailed or complicated for your needs.
    - Golden Gate Parks count everything, but some workers find this to be a distraction from the rest of the work.
    - Variability can be a confounding factor in usefulness of the data (variability among volunteers, plant size, etc.)
- Collect presence AND (especially!) absence data
    - Presence usually collected
    - Absence often more important in weed management
    - Important for early detection (compare with past assessments)
    - Checklists of species?
- Quantify time spent on a site
    - Shows how management needs change over time
    - Helps defend decisions

■ Monitoring: Before, During, After
- Of the three steps (Planning, Eradication, Monitoring), Monitoring can be the most difficult.
    - Effort goes up as plant numbers go down
    - People get bored looking for the "needle in the haystack."
    - Helps to have someone doing it who has ownership in the work

- Be aware of habits and how these may bias your monitoring impressions
- Design your monitoring program early on
- Get scientific advising from University, Extension resources
    - Saves you time from the beginning
    - Better data, especially for time spent
- Techniques
    - Transect density monitoring
    - Rapid Vegetation Assessment
        - CNPS developed
        - CNPS does training sessions
- Set up plots that are appropriate to your needs and time available
    - "Dirty Data" is appealing for projects or organizations with rapid turnover
    - But try to keep design transferable between people and crews
    - Consider the scale of the system and the project. Have a template for several common scales and follow it
- Make sure to bring everyone who is invested in the project to agreement early on
    - Agree on a goal
    - Avoid a disconnect between levels in the organization
    - Clarify plans ahead of time
- All projects involve Adaptive Management!
    - Plans will not always happen as intended
    - Feedback loops lead to new decisions
    - Use new information wisely
    - Consider the worst-case scenario and try to plan it – especially considering weather
    - Don't spend money just because you feel like you're under a deadline.

*Ex: Santa Catalina Island had lots of money to spend and eradicated weeds during two dry years. The third and final year was wet, tons of weeds came up, but by then the budget was mostly gone.*

- Don't be afraid to ask for an extension from your funding agency.
- How to explain Adaptive Management?
    - Can be tricky!
    - Be honest about your expectations and emphasize from the beginning that it is an ongoing battle
    - Last few percent of weeds often cost the most money for the least plants. But it's still important to spend that money!
    - Seedbanks can obliterate all progress when conditions change (i.e. removal of canopy cover due to an insect infestation produces a resurgence of broom) – not much to be done about these situations

- We need to lobby for long-term funding.
    - Look at weed management as maintenance, not an isolated event
    - Use "Maximo" (?) program to detail weed management as maintenance
        - Tracks maintenance events
        - Justifies spending
    - Defends a totally different approach and structure to weed management.
- Summarizing and Stats
    - Check with universities for short-term help, experimental design, etc.
    - Collaborate?
    - Grad students
    - Undergrad student projects
    - Partnerships
    - Student volunteers
    - Coordinate with professors for coursework projects!!
    - Must establish connections and potentially compromise plans to meet mutual goals
- Can get paid interns

**Thanks for a great discussion!**

## Weed Control Q&A: Aquatic Weeds

**Leader:** Florence Maly, California Department of Food and Agriculture

**Facilitator:** Patrick Akers, California Department of Food and Agriculture

***Note taker:*** *Lynn Wihbey Sweet, UC Riverside*

*Participants will have an opportunity to hear about tried-and-true as well as new techniques for aquatic weed control from the perspective of the on-the-ground weed manager. The sensitivity of working in aquatic systems where regulations are especially stringent requires careful choice of weed control options for a good integrated weed management program. Participants are encouraged to discuss their current difficult weed problems and to ask questions of the leaders and the group members. Appropriate for both seasoned weed workers and those new to aquatic weed control.*

### Introduction

- Florence – Perspective from the field: Importance of knowing plants/what you're dealing with. ID's are important. Joe DiTomaso's book is a great resource. Also CDFA botany diagnostics lab. Have to know your waterway, downstream/upstream, uses of the waterway, etc.
- Have to know about and use all available tools: don't rule out hand removal, mechanical methods, physical barriers–be open minded about anything that works.
- If you have resistance issues, use different modes of action. Use available resources to find out which things will work. Herbicide/chemical manufacturer reps, e.g. Monsanto, DuPont and Sepro are good sources of information. Manufacturers' aquatics lines are small though.
- Aquatic weed control takes time! 1989 hydrilla project in Chowchilla River as example. 26 miles of river- 18 years to get to six consecutive years of zero plants.
- Draw-down and fumigant are methods to kill hydrilla tubers in soil. Water drawn down and the treatment is applied with sprinklers. very effective, even though hydrilla is otherwise very difficult to kill. Special permit needed.

### Agencies Involved

- Know the rules and regulations; work with agencies to get regulations.
- Florence – A lot of regulations have changed since 1989
- Question: Waterways- water quality board and Fish and Game jurisdiction?
  - It is important to find out: who owns land under the water? Is it navigable?
  - Fish and Wildlife involvement may be invoked if there are ESA issues.
  - Just call everybody
  - Different activities on same waterway regulated by diff agencies. E.g. bridge/stream alteration would be CA Fish and Game 1600 permit series.
  - Stakeholders can be noisy and disruptive
  - Importance of educating stakeholders
  - If you're calling all agencies, all will WANT to have a say and may not know where limits lie.
- Question: Is there a checklist? County? State?

  If you do an environmental document, you'll trigger whoever needs to know.
- Make sure MOU's and other agreements are written down and counter-signed, etc. Have things down on paper as opposed to undocumented agreements.
- Regional water quality control board is important.
- There are nine regional water quality control boards (each unique).
  - Eg, work on Eurasian watermilfoil and Curlyleaf pondweed in Lake Tahoe, Lahanton RWQCB has a lot of power and vetoes many actions
  - Lake Tahoe effort is made up of an aquatic inv spp working group (people on the ground), then coordinating group (agency people).

Coordinating group talks, find out the issues present then finds funding, ways through regulations.

- There is a need for a listing/description of methods for aquatic plant control- handling boats, herbicide application from boats. A resource to find this information. However, many situations are unique and nearly all will require some customization of methods and equipment.
    - E.g.: *Ludwigia* in Laguna de Santa Rosa in Marin – have to deal with hundreds of tons of vegetation.
- If you can link these problems to things like West Nile, etc. gives you clout with other agencies and stakeholders. For example, Mosquito & Vector Control has machinery and expertise (hovercraft, helicopter, boats, MOU's). Good for cooperative work, a model for work elsewhere. Mosquito control- main target is larva. Control of larvae with mosquito fish- open waterways - will eat stuff up.

### Methods- General

- In general for aquatics- no standard recipe book for methods and actions. Look at different methods, and what you have vs. what you need, what options you have available to you. Customized projects are common. Redevelop procedures (site-specific). Although there are standards, and standardized equipment, you sometimes need to take sprayers and agricultural equipment, and adapt it for aquatic use.
- Again, important point is to not discount potential treatment methods till you have tried them
- Question: When can you use backpack sprayers?
    - For floaters/emergent
- Question: What about submerged species?
    - Several herbicides available and effective in slow-water situations, depending on species. But you need ID's and life history information, and know what you have.
    - Difficult if there is flow- most difficult situation
    - However, do not assume methods won't work without trying them.

Boating and Waterways situation very instructive. They are trying to control *Egeria densa*, a submerged weed, with fluridone, a slow-acting systemic herbicide. Supposedly you need three weeks of contact time with fluridone to get effective control. They are trying to control the egeria in Frank's Tract, a tidal area where there is lots of water movement. The first guess would be that the control wouldn't have a chance of working, but B&W is starting to see promising results. How is this happening? May be that it's getting moved off and on again due to the tides.

- Some of these methods are novel and getting this information into the literature is important.
- Control of aquatic plants- This subject has blossomed in the last 15 years. No cookbook yet. We're not ruling anything out yet.
- Always need to take population prioritization into account. Start small.

### Survey and Monitoring

- Question: What if surveys haven't been done?
    - These need to be done. You at least need to know which species you have.
    - We use a crude grappling hook to reach down and see what we have (15 gauge wire bent through a 6-8 inch section of heavy pipe). Rebar, or a weed rake
    - Pat Handout: As long as we are talking about surveying and mapping; a GPS system to use for doing this. Device- can customize for your needs. Integrated with a GPS recorder, make records of up to eight spp at one time, and takes only a few seconds for each observation.
- Question: Can it do elevation under water? Not at present. Manufacturer is very willing to customize system and if you can get a signal out of your sonar system, he can probably get it recorded with the GPS data
- Question: So is one of the treatment methods to make environment non-aquatic?

- Yes, draw-down is useful to control some species, but it will actually encourage other species. Look those up

- Most of the submerged species are rooted perennials, not annuals.
- Again, know particular species and your waterway.

### Species Information and Identification

- Question: *Elodea*- where is it native?
  - Pat – The major pest species is *Egeria densa* and is non-native. Comes from South America. It has several common names including egeria, Brazilian elodea, or just elodea. Problem is, there are two species of native *Elodea* (*canadensis, nutalli)*, so I always call it egeria to avoid confusion. They are all somewhat similar in appearance.
  - Florence – Just because a plant is native doesn't mean it's not a problem.
  - Pat – But native *Elodea* don't tend to be a nuisance.
  - Native vs. non-native water primrose *Ludwigia)*: They have *Ludwigia hexapetala* – the non-native - at Laguna de Santa Rosa. They did chromosome squashes, figured out what it was. Used morphological characteristics to get ID. Keys from Jepson weren't working
- Question: Who can we ask about this in Sacramento?
  - Send it to an expert, e.g., Lars Anderson, Joe DiTomaso.
- Need healthy, flowering plants to identify *Ludwigia*. If petal is longer than 2cm, you have *hexapetala*. Fortunately, Ludwigia flowers almost constantly.
- There is six miles of this on Seal Head creek.
- *Ludwigia* can be very hard to tell apart when not healthy and flowering. One experience was that often using the Jepson key leads to non-native ID.
- Some of the natives can be aggressive though.
- With native plants and California's many climates due to north-south spread, elevational differences, really can have isolation and differentiation between populations, natural dispersal barriers. So some natives can be invasive even within California, e.g., yellow bush lupine from Southern California is invasive north of SF Bay.
- Bakersfield- 3000 acres of water hyacinth in water infiltration ponds- comes in from other places.
- Maryland experiment in water infiltration ponds- tried radishes; cows eat off tops, roots rot and battle weeds, improve percolation.
- Need to look at situation and be creative.
- Pat – Water primrose? How many have experienced trying to control it?

  (4/12 present)
- We've needed to control it, have gotten mixed responses using triclopyr. May be because we're using diquat as well, and the diquat is killing the top before the triclopyr can move through to the roots and kill them. We'll try to get better control by doing triclopyr treatments a couple of weeks before the diquat treatments.

### Methods- Timing and Biomass:

- Experience of contract work- usually the situation is way out of control when it gets to the contractor. Usually there's lots of biomass that must be removed at that point. Have used a variety of herbicides after. Renovate (=triclopyr) works the best (on water primrose). Renovate alone is best product out there and best success rate. Need to treat plants on shoreline too! That's the population reserve. Spray bank as well- that's where it starts from. Tough plant to handle.
- Question: So remove biomass first, and then maintain control of resprouts?
  - Yes. Example of a lake 4' deep- put in mechanical equipment to remove it- the aquamog and harvester (clamrake) pulls it.
- Question: What do you do with sheer biomass?
  - Depends on situation. City of San Francisco to it and made compost, and is a good weed suppressant (recommended for areas away from waterways). Lots of biomass though.

- If you maintain your site, you won't end up with this situation. Once past this task, should be less work on maintenance.
- Question: So what do you do with the biomass?
    - Another possibility was used in Laguna de Santa Rosa: arrange with local farmers to dump, they'll disc it in. But with very polluted waterways, can have significant garbage in haul of biomass.

**Methods- Preventative measures:**

- Pat – Mechanical methods make many plant fragments, and many aquatic species spread easily by fragments. Can be a source for new infestations somewhere else. If an infestation is small and is the first one on a water body, mechanical methods can rapidly spread the infestation. So you need to know if you'll only be making the situation worse if you do mechanical control.
- In contract work, sometimes a boom is placed around the area. Helps also with turbidity.
- Question: What is a boom?
    - A physical barrier that allows water through but not sediment. Doesn't restrict flow or movement of water.
- Lake Tahoe- A person on the boat looks for turbidity. Watch for too-high levels, then stop work. Turbidity is really a short-term impact though if you look at larger goal. So haven't used booms etc. More for safety of divers.

**Methods- Solar Bees**

- Solar Bees in the ponds? Common misconception that they'll get rid of aquatic weeds. They are for algae. Don't do anything for macrophytes. They are expensive.
- Solar Bees are not for rooted plants.
- Again, one must know the plants present before starting all of this.

**Seasonality and Timing:**

- Suggestion: Dig up roots, and treat, etc. Try to get back to a situation where you're just treating occasionally instead of waiting until you can't see the water any more.
- Question: Is there an issue of seasonality of treatments?
    - Plants are pretty dormant in the winter, and often biomass dies way back. Many times you can take advantage of this. Conversely, sometimes treatments later in the season are much less effective, because there's much more to treat than there would have been earlier.
    - If you're managing lake, don't cut aquatic every year: aquatic plants love to be cut and re-grow rapidly. Water primrose- very expensive. For extreme nuisance conditions.
    - Two techniques- apply herbicide first, remove biomass second? Or vice-versa? Depends on scale. Biomass should come out first.
    - The seasonality issue depends on the plant species.
- Water hyacinth- You are already behind if you start treatment in July. Do treatments in April/May.
- You may be treating biomass that would disappear in winter anyway. Fluctuates by 80% annually. If you spray just before senescence, results may be natural die-off and not herbicide effects.
- Water primrose- Perennial. Treat as soon as you can once growth starts.
- Many perennials- Treat towards end of season- good time to treat with systemic herbicides. Will pull down to root.
- Salmonid areas (waterways with salmon) Spray is prohibited at certain times. Can't spray until after June 15 unless you get a take permit.
- Question: Is there is a window for control before this season relative to salmonids?
    - Boating and Waterways does the hyacinth control, not CDFA. They have the permits. There may be some local treatments in April that are allowed in certain small cases.
    - Probably can't treat before the salmon season due to biology of plant, ie, they are dormant anyway, so treating is useless.
    - Boating and waterways has spent money on studies- knows why these regulations are in place.
- Fall River Mills? PG&E was harvesting biomass of aquatic weeds to make sure

waterways clear, flow moving. They weren't concerned with fragments entirely, but they did use booms to catch fragments. This program was discontinued due to lack of funding. Situation hasn't worsened too much yet, but there have been no big floods since then. May depend on water temperature for aquatic plant population blooms.

- Cut the tops at 4' depth, cut in swaths.

**Resources:**

- Question: What are some good online resources?
  - Joe Ditomaso's book.
  - CDFA website- not for control, but weed ID.

# Poster Session

## Student Poster Session

### Evaluating the Potential for Spread of an Invasive Forb, *Limonium ramosissimum*, in San Francisco Bay Salt Marshes

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Invasive species threaten to alter the outcome of San Francisco Bay's tidal marsh restoration efforts. In 2006 and 2007, Algerian sea lavender (*Limonium ramosissimum*), a salt tolerant invasive forb prevalent in southern California marshes, was found in restored and disturbed marshes in San Francisco Bay. While this suggests future restoration sites are at risk of invasion by *L. ramosissimum*, the extent to which the plant has invaded and the elevational range of greatest potential impact is unknown. To address these questions, we located and mapped invasive *Limonium* populations in San Francisco Bay and are surveying soil and vegetation parameters in three invaded marshes. Mapping results show all eight populations of *L. ramosissimum* are clustered on the southwest edge of the Bay with the largest populations centrally located, suggesting spread is occurring north and south along the Bay's western edge. Initial survey results of three invaded marshes show *Limonium* is present in the mid to high marsh and is commonly interspersed with *Sarcocornia pacifica*, *Jaumea carnosa*, *Distichlis spicata* and *Grindelia stricta*, indicating *Liminium*, unlike many other invasive plants, is not restricted to marsh edges. Near total monocultures occur in the high marsh where *Limonium* grows on average 8 cm taller and produces 22 more flowers per plant than in mid marsh elevations, suggesting rare species growing at high marsh elevations are at greatest risk. The results of these studies will help determine where, within future restored marshes, invasions are likely to occur.

### Effects of Disturbance of Biological Soil Crusts on the Emergence of Exotic Plants in California Sage Scrub

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Invasion by nonnative species is shifting the composition of California sage scrub (CSS) from native perennial shrubland to exotic annual grassland. Disturbance of biological soil crusts (BSCs) is hypothesized to increase emergence of exotic plants. BSCs, comprised of soil particles and cyanobacteria, green algae, fungi, lichens and bryophytes, occupy the soil surface and provide integral ecosystem services in myriad abiotic-stressed systems, including CSS. Using a field and greenhouse experiment, I tested the hypothesis that disturbance of BSC increases emergence of exotic plants in a coastal CSS plant community. At Whiting Ranch Wilderness Park in Lake Forest, California, 42 paired subplots were established and emergence of exotic and native plants was compared between control subplots containing intact BSC and disturbed BSC subplots. In the greenhouse experiment, intact BSC cores were extracted from CSS and half were disturbed. Seeds of exotic and native plants were placed in BSC cores by species and then observed daily to determine seed fate (emerged, missing, or did not emerge, $n = 6$). In the field, disturbance of BSC significantly increased total exotic emergence (Wilcoxon-signed rank test, p

$< 0.01$). Total emergence of native species did not differ between treatments (Wilcoxon-signed rank test, $p < 0.69$). In the greenhouse, seed fates significantly differed between treatments for all exotic species (contingency analysis, $p < 0.0001$). Results for native plants were species specific. These results will assist CSS land managers by considering BSCs as an ecological structure affecting exotic plant invasions and a component of overall ecosystem health.

## Soil Biota Influence Invasion within Microhabitats in a California Coastal Prairie

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*Peter Alpert, University of Massachusetts at Amherst, Amherst, MA. *taraneh.emam@gmail.com*

### Abstract

Relationships between plants and soil biota greatly influence the ability of non-native plants to invade native communities. Soil biota, and plant-soil interactions, can vary widely between microhabitats. On the Bodega Marine Reserve (BMR), soil microhabitats influenced by *Lupinus arboreus* have been shown to facilitate growth of non-native grasses through increasing soil nitrogen availability. This study compared biomass accumulation and emergence of a common native grass (*Hordeum brachyantherum*) and a prolific non-native (*Bromus diandrus*) on live and sterile soils from native grassland and the rhizospheres of *L. arboreus* and *B. diandrus* in order to determine the effect of soil microbiota. Results showed that although lupine soil increases the biomass of *B. diandrus*, this effect is diminished by the presence of soil biota; biomass of *B. diandrus* increased by 13.5% on sterile lupine soil. While *B. diandrus* biomass was reduced by 21.8% on sterile grassland soil, *H. brachyantherum* biomass was increased by 12.9%. Emergence of *H. brachyantherum* was also increased on sterilized grassland soil by 58.3%. Emergence of *B. diandrus* increased by 11.8% on sterile grassland soil, 11.1% on conspecific soil, and 26.7% on sterile lupine soil. Both emergence and biomass of *B. diandrus* were most inhibited by lupine soil biota and *H. brachyantherum* was much more inhibited by grassland soil biota than *B. diandrus*.

### Introduction

Only a small proportion of introduced plant species become aggressive invaders. Recent research has shown that relationships between plants and soil biota are key in determining the invasibility of an ecosystem (Klironomos 2002, Reinhardt and Callaway 2006). Additionally, the ease with which an invasive plant becomes established is known to vary across microhabitats (Kolb *et al*. 2002). Within a single landscape, many microhabitats may exist; defined by variation in nutrient availability, water availability, abiotic and biotic soil characteristics, and microclimate. Increased nitrogen availability in soil influenced by *Lupinus arboreus* has been shown to facilitate invasive grasses on the Bodega Marine Reserve (BMR) (Maron and Connors 1996, Alpert and Maron 2000). Although nutrient availability is of great importance, there are numerous other factors that determine the invasibility of a microhabitat; this paper will focus on the role of soil microbiota to add to previous research.

In order to better understand biotic soil factors influencing invasion, this study examined how soil communities from differing microhabitats on the BMR affect the growth of both the native grass *Hordeum brachyantherum* and the non-native *Bromus diandrus*. The objectives of this study are: i) to determine whether soil biota from lupine and grassland rhizospheres differentially influence the speed and rate at which *B. diandrus* and *H. brachyantherum* emerge, ii) to determine whether biomass accumulation is affected by soil biota, and iii) to compare the relative feedbacks of conspecific soil on the emergence and biomass accumulation of both grasses.

## Study Site and Methods

Research was conducted using soil and seeds collected from the University of California, Davis Bodega Marine Reserve on the central California coast. The BMR supports a relatively pristine coastal prairie as well as grassland invaded by annual grasses including *Bromus diandrus*. Large populations of *Lupinus arboreus* dominate much of the prairie, and the resulting increase in soil nitrogen in their rhizospheres has been shown to promote the growth of non-native species. Three soil types from the BMR were collected in February 2008, from underneath lupines at least 1m in diameter ("lupine" type), native-dominated grassland adjacent to but at least 1m away from lupine bushes ("grassland" type), and large individuals of *B. diandrus* at the edges of the native grassland ("invaded" soil type). Soil from six sites per type was collected from the 5-15 cm layer, pooled separately, and mixed well.

The majority of each soil type was sterilized by autoclaving for one hour at 121° C three times with three days in between each (modification of Meiman *et al*. 2006). A "live" treatment consisted of four parts sterilized soil combined with one part live soil that had been retained (A. Bennett, personal communication). The sterilization-plus-reinoculation method was used to account for some of the changes in soil characteristics that occur during autoclaving. Twenty pots containing one seed each were created using live and sterile soils of each type for *H. brachyantherum* and *B. diandrus*, with the exception that only *B. diandrus* was sown on the invaded soil type. Plants were grown in the Mills College greenhouse (Oakland, CA) and were harvested after forty two days, dried at 65 °C for four days and weighed. Statistical analysis was conducted using JMP 7 and Microsoft Excel 12.1.0. Tests conducted were student's t-test, multivariate ANOVA, and Fisher's Exact Test. Significance is defined as $P < 0.05$. Relative effects of live soil on biomass, rate of emergence, and time to emergence are reported as:

[(average on live soil – average on sterile soil)/ average on live soil] x 100%

## Results and Discussion

***Biomass*** Results indicated that although the nitrogen present in lupine soil increases biomass, this effect may be minimized by the presence of soil biota within lupine rhizospheres. Both *H. brachyantherum* and *B. diandrus* accumulated significantly more biomass on both live and sterile lupine soil than on other soil types ($P = 0.0005$ overall), undoubtedly due to the higher levels of nitrogen found in lupine-influenced soil (Maron and Connors 1996). The difference in biomass was significant for both species between sterile lupine soil and other sterile soils (compared to grassland $P = 0.04$ for *H. brachyantherum*, $P < 0.0001$ for *B. diandrus*; $P = 0.003$ for *B. diandrus* compared to invaded). On live soils, the difference in biomass for *B. diandrus* was significant between lupine and invaded soils ($P = 0.03$), but not between lupine and grassland soils. Likewise, *H. brachyantherum* did not show a significant difference between live lupine and live grassland soils (Figure 1).

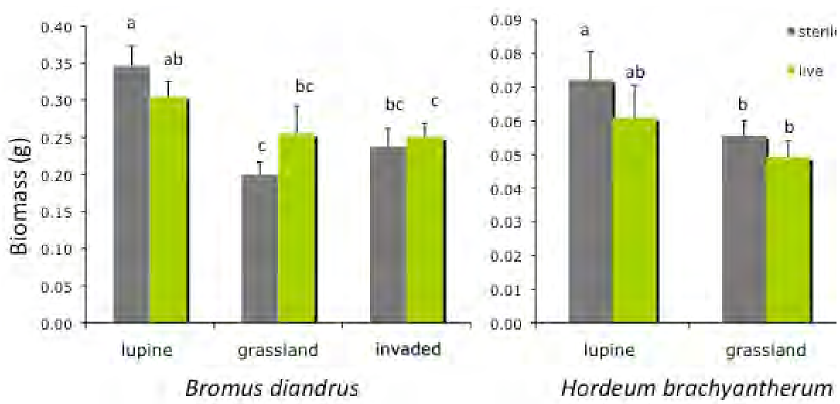


Figure 1

Biomass accumulation of both *B. diandrus* and *H. brachyantherum* was highest on sterile lupine soil. Note that *B. diandrus* accumulated more biomass on live grassland and invaded soils than on sterile. Letter indicate significant difference ($P<0.05$). Bars show standard error.

The relative effect of live soil on biomass accumulation was comparable between *H. brachyantherum* and *B. diandrus* on lupine soil (Figure 2). However, in native grassland soil, *H. brachyantherum* biomass was reduced in the presence of soil biota by 12.9%, but *B. diandrus* biomass increased with live soil by 21.8% (Figure 2). This may indicate that *B. diandrus* is experiencing enemy release from soil pathogens when initially colonizing native grassland.

On the invaded soil, *B. diandrus* experienced a slight positive effect of live soil, however, this

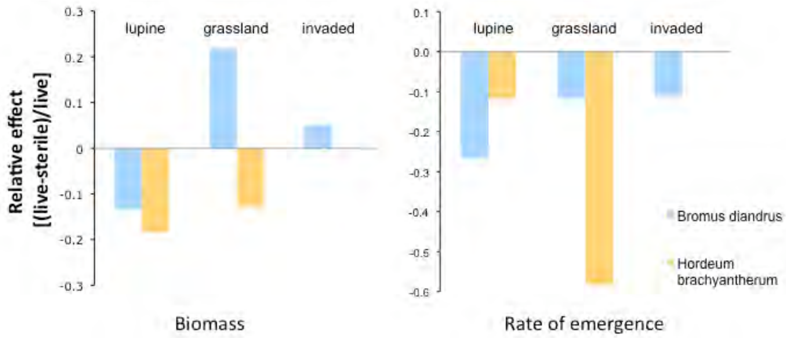


Figure 2

The relative effect of live soil on biomass accumulation and rate of emergence for *B. diandrus* and *H. brachyantherum*. While *B diandrus* experienced a positive effect of live grassland soil on biomass, *H. brachantherum* experienced a negative effect. The negative effect of live grassland soil on emergence was much greater for *H. brachyantherum* than *B. diandrus.* Both had similar responses to live lupine soil. Allthough live invaded soil slightly increased *B. diandrus* biomass, it decreased emergence.

effect was much reduced compared to that of the native grassland soil that surrounds the invaded soil type. This may suggest that growth of *B. diandrus* increases specific soil antagonists that reduce the positive effect of native grassland over time.

***Rate of Emergence*** While *H. brachyantherum* is hindered by biota in native grassland soil, it is not significantly affected by biota found in lupine rhizospheres and for *B. diandrus* the opposite was found to be true. Emergence of both species was greater on sterile soil than live soil for all soil types ($P = 0.001$ overall). Between live and sterile soil for individual soil types, *B. diandrus* emergence was noticeably greater on sterile soil for lupine soil ($P = 0.09$), but less so for grassland or invaded soil (Figure 2). In contrast, *H. brachyantherum* emergence was significantly higher on sterile grassland soil than live ($P = 0.001$), but not significantly different between live and sterile lupine soil. The effect of invaded soil on *B. diandrus* emergence was similar to that of grassland soil (Figure 3); contrary to the biomass results it appears that growth of *B. diandrus* does not increase soil antagonists that reduce its emergence.

***Time Until Emergence*** While no significant differences were found between soil types in regard to the speed of emergence, an interesting trend was documented (data not shown). While *H. brachyantherum* emerged more slowly on live soils for both lupine and grassland soils, *B. diandrus* emergence was faster on live soils for all three types. Though this was not statistically significant ($P = 0.13$), this finding may warrant additional research.

## Acknowledgements

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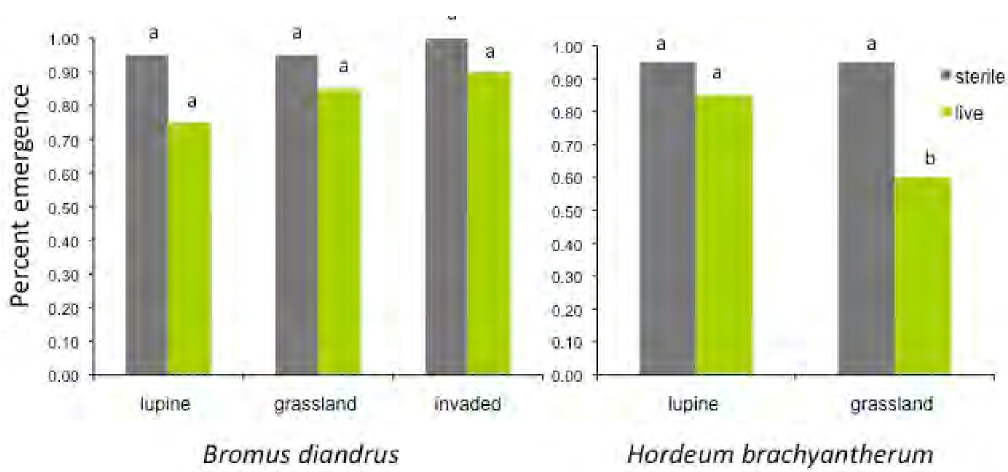


Figure 3

Emergence rates of B diandrus and H. brachyantherum. While differences between live and sterile soil were not significant for B. diandrus within individual soil types, H. brachyantherum emerged at a significantly lower rate on live grassland soil. Letter indicate significant difference (P,0.05). Bars show standard error

# Interactive Effects of Population Genetic Diversity and Resident Community Composition on the Success of an Annual Exotic Invasive Species

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**Abstract**

Ecological theory predicts that the success of exotic invasive species may be affected by the genetic diversity of the invasive population as well as the species composition of the invaded community. We tested how exotic population genetic diversity and resident community composition affected the success of the invasive annual grass, *Avena barbata*. We tested whether: 1) increased genetic diversity of the exotic population caused increased invasion success, 2) diverse resident communities better resisted exotic invasion, and 3) resident communities composed of species functionally similar to the exotic better resisted invasion. In a fully factorial greenhouse experiment, we established resident communities which varied in species diversity (1, 2, or 3 species) and functional group composition (annual grass, perennial grass, and annual forb). These communities were invaded by *A. barbata* populations, which varied in genetic diversity (1, 5, or 10 genotypes). We measured invasion success using above ground biomass of *A. barbata*.

There was a significant, positive effect of genetic diversity on *A. barbata* performance, while increasing resident community diversity decreased *A. barbata* performance. There was a negative main effect of the presence of *Nassella pulchra*, indicating that the presence of a perennial grass, not the functionally similar annual grass, was responsible for increasing community resistance to invasion. However, in functionally similar communities (composed of annual grass) increased genetic diversity positively affected *A. barbata* performance. These results indicate that understanding the interaction of invasive genetic diversity and resident community composition may be important for predicting potential invasiveness of exotic species in differing communities.

There are a limiting number of resources available to any given plant community. During invasion scenarios native and exotic species are in direct competition for these limited resources therefore invasion success may be dependent on competitive outcomes. Two likely scenarios are 1) an invasive population can partition available resources with the resident community increasing its invasion success; 2) the resident community can effectively use all available resources and resist species invasion.

Ecological theory predicts that species-rich communities will outperform species-poor communities because trait differences among species allow them to partition and more effectively use natural resources (Hooper and Vitousek, 1997). Since individual genotypes of a particular species have trait differences analogous to those expressed by individual species, genetic diversity should be mechanistically equivalent to species diversity (Reusch et al. 2005, Vellend and Geber 2005). Thus, as genetic diversity increases, population performance is predicted to increase because genotypes with varying traits more effectively partition limited resources. Genetically diverse invasive populations are therefore predicted to have increased invasive success. Alternatively, resident community species diversity may lead to better invasion resistance. The more diverse the community, the greater the chance it effectively uses all available resources and limits those available to the invader, particularly if the community contains resident species with traits similar to the invader (Symstad, 2000).

We conducted a mesocosm greenhouse experiment to test three hypotheses concerning invasive success. 1) Increased exotic genetic diversity will cause increased invasion success; 2) functionally diverse communities should better resist exotic invasion regardless of the genetic diversity of the invasive population; 3) Resident communities that share similar traits to the invader should resist exotic invasion regardless of the genetic diversity of the invasive population.

## Methods

We tested our hypotheses in the context of invasion in California grassland communities. Resident community species were chosen to exhibit a range of plant functional types common in California grasslands and organized based on their similarity to the exotic invader (the annual grass *Avena barbata*) according to growth patterns: annual grass (*Lolium multiflorum*), perennial grass (*Nassella pulchra*), and annual forb (*Amsinckia menziesii*). In a fully factorial design, communities were established by manipulating species presence (annual grass, perennial grass, and annual forb) and species diversity (1, 2, or 3 species) then invaded with *A. barbata* populations that varied in genetic diversity (1, 5, or 10 genotypes) for a total of 63 pots. Communities were established based on natural growth form at the beginning of the rainy season in California (annual species = seeds, perennial species = small plants) and planted in even distribution in three-gallon greenhouse pots in Sunshine Mix #1 potting soil at a density of 20 individuals per pot. *Avena barbata* was planted as seeds at a density of 10 seeds per pot. Soil was kept moist (volumetric soil moisture content >10%) and fertilized with 200mL Miracle-Gro™ 20-20-20 once every seven days.

At peak biomass (approximately three months) all above-ground biomass was harvested by species and dried for 48 hours at 60$^{o}$C. Relative invasive success was assessed using *A. barbata* average individual dried above ground biomass (g). This response was natural log transformed before analysis to increase normality and variance homogeneity. We chose to use an ANOVA model for analysis based on the categorical nature of the factors and the use of a fully factorial experimental design. The model assessed the main and interactive effects of *A. barbata* genetic diversity (1, 5, 10 genotypes), resident community diversity (1, 2, 3 species), and resident species (presence, absence).

## Results

Exotic species genetic diversity had a positive main effect on *A. barbata* average individual biomass (Figure 1, F=4.37, P<0.05). Increasing genetic diversity from one to ten genotypes increased average individual *A. barbata* biomass 37%. Community diversity had a significant main effect on *A. barbata* average individual biomass (Figure 2, F=57.42, P<0.001). Increasing community diversity from one to three species effectively decreased average individual *A. barbata* biomass by 47%. The presence of a functionally similar annual grass species (*L. multiflorum*) did not contribute to a decrease in *A. barbata* biomass (Figure 3, F=0.31, P>0.05),

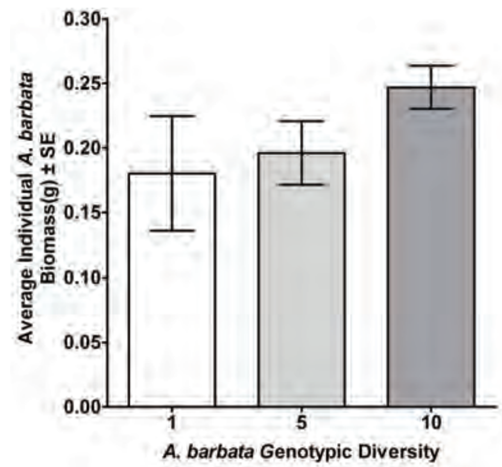


Figure 1

Increased exotic genetic diversity caused a signification increase in individual *A. barbata* biomas (P<0.05).

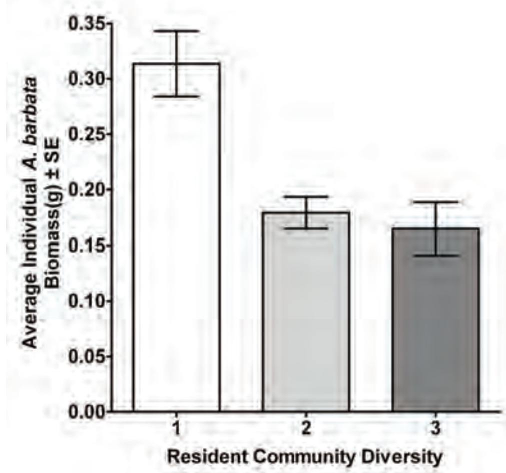


Figure 2

Individual *A. barbata* biomass was significantly decreased by increasing resident species diversity (P<0.05)

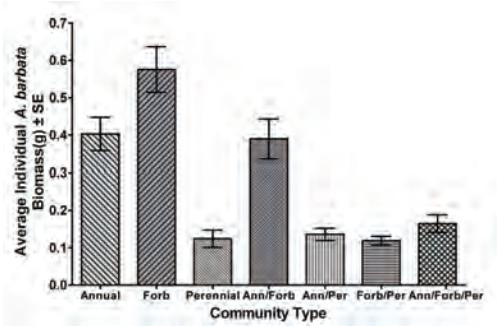


Figure 3

Communities that were functionally similar to A. barbata not better resist invasion (p<0.05). Instead, communities that contained the perennial N. pulchra resisted invasion best (p<0.001)

but the presence of a perennial grass (*N. pulchra*) significantly decreased mean individual *A. barbata* biomass (Figure 3, F=49.88, P<0.001). Finally, there was a significant interactive effect of *A. barbata* genetic diversity with the presence of the annual grass (*L. multiflorum*) in the resident community (F=3.69, P<0.05).

## Discussion

Ecological theory predicts that genetically diverse exotic species will have increased invasive success and species diverse communities and communities functionally similar to the exotic will have increased invasive resistance. This experiment provided support for all three effects.

***Invader Genotypic Diversity*** Genetically diverse invasive populations had increased invasive success (Figure 1) especially in communities containing annual grass species, which are functionally similar to *A. barbata*. This suggests that genetic diversity may be an important predictive indicator of invasive success, especially under specific invasion scenarios. In natural communities, the genetic diversity of exotic species populations is predicted to increase with the increased rate of multiple introductions. Therefore understanding the impacts of genetic diversity on invasive potential is essential. A thorough understanding may help researchers assess and identify potential invaders in varying habitats and community types.

***Community Diversity*** Community diversity significantly decreased invasion success (Figure 2). These results indicate that diverse communities may be able to efficiently use all environmental resources or may fill all available environmental niches and successfully exclude potential invaders. Protecting biodiversity in natural communities may be an effective way to reduce invasion.

***Functional Similarity*** The presence of a functionally similar annual grass species did not decrease overall invasive success (Figure 3). Instead, the presence of a native perennial grass was responsible for a decrease in *A. barbata* invasive success (Figure 3). Our perennial grass, *N. pulchra,* was once a dominant species in California grasslands and seems to provide resistance to exotic annual grass invasion suggesting that mechanisms other than competition are responsible for the historic type shift from perennial to annual grassland communities. These data also suggest that *N. pulchra* may be an ideal species for use in California grassland restoration where reinvasion by annual exotic grasses may be a problem.

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# Spatial Patterns in Native and Exotic Submersed Aquatic Plant Species in the Sacramento-San Joaquin River Delta

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## Abstract

Submerged aquatic plant species (SAPS) act as ecosystem engineers and service providers, affecting the dynamics of freshwater ecosystems. The Sacramento-San Joaquin River Delta is an example of an aquatic ecosystem highly modified by the effects of human activities and biological invasions. At the regional scale, the SAPS community is undergoing modification towards an exotic species dominated plant community. We have monitored the spatial distribution of the SAPS community since 2003 to 2007 using hyperspectral remote sensing. In the areas with consistent SAPS presence, we sampled species composition. Our results show that the SAPS community is composed of four native and four non-native species, with the non-native *Egeria densa* being the most frequently detected species in monospecific stands followed by the native *Ceratophyllum demersum*. These two species frequently co-occur and have a generalized distribution throughout the area. The native and exotic species share available niches (58% overlap; 1779.6 ha), with exotics occupying a greater area (3092.07 ha) than natives (2069.9 ha). This shift toward non-native invasive species dominance irreversibly alters the native community composition; however, further research is encouraged to assess functionality at the ecosystem level.

## Introduction

Submersed aquatic plant species (SAPS) serve as service providers and ecosystem engineers (Jones *et al*. 1994). These plants provide erosion stabilization, water retention and supply, nutrient cycling, and habitat to support and protect associated fauna (Groot *et al*. 2002). SAPS, acting as ecosystem engineers, trap floating sediment particles, raise river bed levels, increase water clarity, impede light penetration, steepen the vertical temperature gradient, decrease water velocity, alter flow-patterns, and ultimately change river channels' water velocity. These roles, however, are threatened when the native community of SAPS is replaced by non-native, fast growing and ecologically competitive invasive species which may not exhibit similar ecosystem functions.

Biological invasions in the Sacramento-San Joaquin River Delta have altered SAPS composition (Anderson 1990) towards a shared native – *Ceratophyllum demersum* , *Stuckenia pectinata*, *Elodea canadensis*, and *Potamogeton nodosus* – and non-native community – *Egeria densa*, *Myriophyllum spicatum*, *Cabomba caroliniana* and *Potamogeton crispus*. Despite their presence over the last two decades, the actual spatial distribution of each species has not been adequately mapped, nor have their interactions (co-existence, competition, facilitation, etc.) been documented. We monitored the community and species distributions using remote sensing, field sampling and spatial analysis methodologies. Our goals were to estimate SAPS spatial distribution, assess geographic overlap between native and exotic species, and determine species interactions.

## Methods

The study was conducted in the central area of the Delta (6,400 ha). This area is characterized by a dynamic hydrological system, where increasing anthropogenic activities have dramatically changed natural flow patterns. This has substantially altered habitats of emergent, floating, and submersed aquatic plants.

We used a hierarchical decision tree applied to HyMap hyperspectral imagery (3m resolution, see Hestir et al. 2008) to map the distribution of SAPS community from June 2003 to 2007. Accuracy was assessed using producer's and user's accuracy, and kappa statistics (Cohen 1960).

Species composition was determined in October 2007 using a long-handled, double-headed garden rake (Kenow *et al*. 2007). We rated the proportion of individual species collected in each rake measurement. We calculated relative frequency of each species, species richness and diversity, frequency at which species co-occur, and overall community richness and diversity using Simpson's and Shannon's diversity indexes. The geographical coordinates of each sampling location were recorded using a GPS device and used to assess SAPS spatial distributions through a kernel-density method.

## Results and Discussion

SAPS community spatial distribution showed a significant increase in SAPS areal cover until 2006 ($R^2$= 0.94), followed by a major decrease ($R^2$= 0.13) (Figure 1, Table 1). The observed decrease in the last two years is associated with *E. densa* herbicide treatment in Franks Tract.

We detected the eight target SAPS. Species richness showed "hotspots" in the SW corner of the study area and the central Delta inundated islands (Figure 2). SAPS community had an overall Simpson diversity of 1.75 and Shannon diversity of 0.94. The observed SAPS richness is similar to that reported for the Mississippi River (Kenow et al. 2007), the Potomac River (Rybicki et al. 2001), the St Laurence Lake (Vis *et al*. 2003), and lakes in Maine (Hunter et al. 1986);

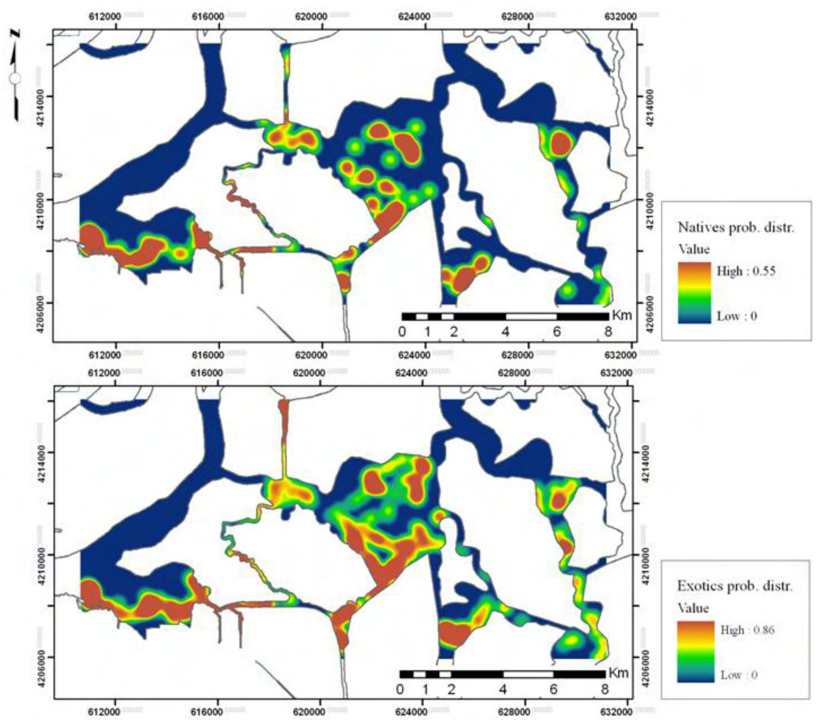



Figure 2

Ground-based spacial distritution of native (top) and exotic (bottom) SAPS in the Sacramento San Joaquin River Delta

| | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|
| SAPS Area (ha) [% cover] | 341.96 [5.34] | 891.72 [13.93] | 1009.2 [15.77] | 1381.28 [21.58] | 550.97 [8.61] |
| Accuracy (%) | 83.5 | 75.1 | 87.8 | 80.2 | 80 |

Table 1

Area and percent cover of SAPS community detected by hyperspectral remote sensing.

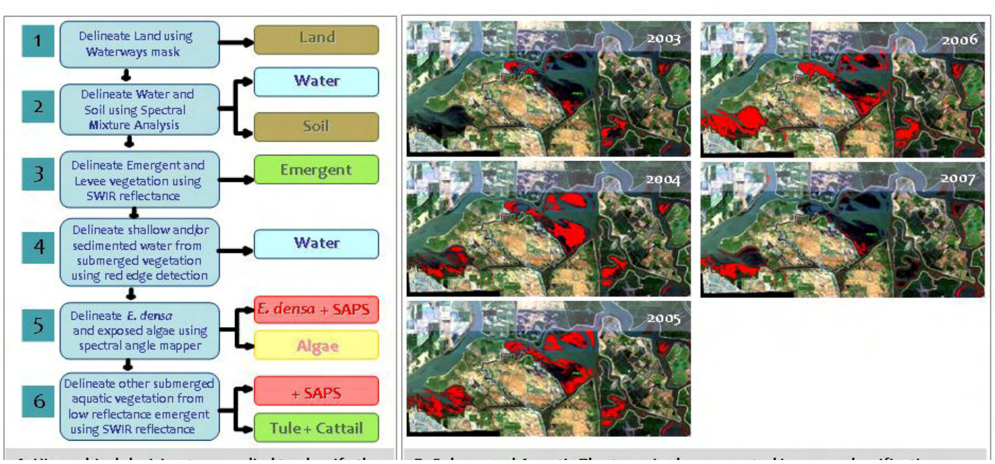
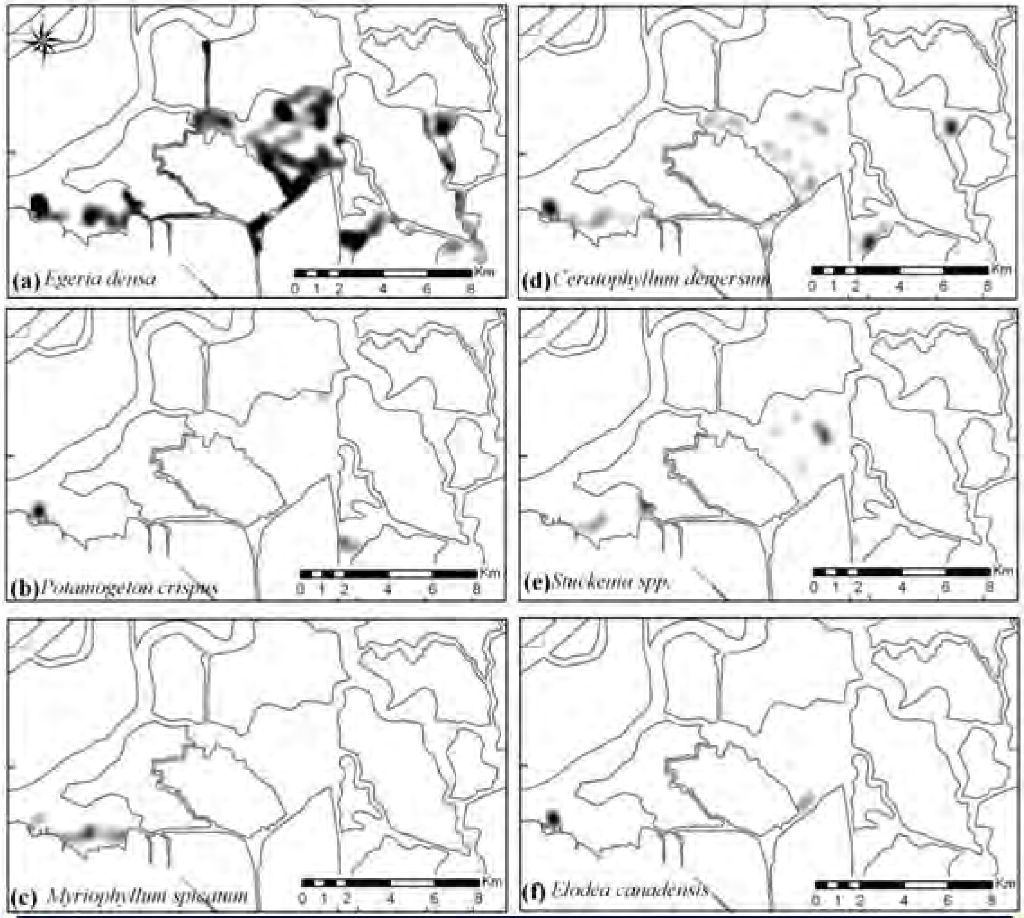



Figure 1

A - Hierarchial decision tree used to classify SAPS in the Sacramento San Joaquin River Delta

B - Classification results from 2003 to 2007 for SAPS over the central Delta




| Scientific name | n | Relative Frequency (%) | Area (ha) | % cover |
|---|---|---|---|---|
| ***E. canadensis*** | 19 | 2.94 | 57.57 | 0.90 |
| ***C. demersum*** | 139 | 21.52 | 838.43 | 13.10 |
| ***Stuckenia spp.*** | 25 | 3.87 | 146.42 | 2.29 |
| ***P. nodosus*** | 1 | 0.15 | NA | NA |
| ***E. densa*** | 339 | 52.48 | 1091.07 | 17.05 |
| ***M. spicatum*** | 31 | 4.80 | 202.21 | 3.16 |
| ***C. caroliniana*** | 1 | 0.15 | NA | NA |
| ***P. crispus*** | 23 | 3.56 | 129.69 | 2.03 |

Figure 3

Kernal distributions ofr each of the target species and statistics for the central area of the Sacramento-San Joaquin River Delta a) *E. densa*, b) *P. crispus*, c) *M. spicatum*, e) *Stuckania spp.* and f) *E. canadensis*. Due to the low detection rate of *P. notosus* and *C. aroliniana*, distribution kernels were not derived.

however, in the Delta, the ratio of native to exotic species is higher (4:4) than that for those other systems (1:6, 1:14 or 2:5, respectively).

Native and exotic species show 58% overlap in their distributions (1779.6 ha; 27.81% of the waterways), with exotic species covering a larger area (3092.07 ha; 48.32% of the waterways) than natives (2069.9 ha; 32.35% of the waterways) (Figure 2). SAPS spatial distribution seems to be restricted by water flow conditions. In Franks Tract, the central area and areas in and around levee breechings have mostly tide-generated, high water velocity which hinder establishment; however, the remaining shallower and slow water flow areas of this inundated island have been colonized by these species.

*E. densa* was detected in 58.6% of the samples (Figure 3), followed by *C. demersum* (24.1%). On average we recorded 1.49 species, with a maximum of four species, at a site. Average Shannon diversity in the samples was 0.21 and Simpson diversity was 1.26, indicating that the community is dominated by abundant common species. *E. densa* had widespread distribution; *C. demersum* and *Stuckenia* spp. had a spatially limited distribution (Figure 3). These results are consistent with colonization patterns of *E. densa* in other aquatic systems (Wells et al. 1997, Carrillo et al. 2006). *E. densa* displaced other SAPS after it became established; however, *E. densa*'s dominance is dependent on community composition. For example, in Lake Marion it was overgrown by *Hydrilla verticilata* because *E. densa* cannot occupy the near-surface high-light habitat (Kozlowski 1991).

*E. densa* occurred mostly in monospecific patches (33.28%), or in mixed patches with *C. demersum* (25.78%). *C. demersum* mostly co-occurred with other SAPS (22.13%) and infrequently in monospecific patches (2%). The remaining species mostly co-existed with *E. densa* and *C. demersum*. The high degree of co-occurrence between *E. densa* and *C. demersum* has not yet been reported. The most plausible mechanism is that *E. densa* facilitates *C. demersum* establishment and development. Since *C. demersum* has no roots (Kautsky 1988), it is limited to slow flowing areas or to entangling with other rooted macrophytes, such as *E. densa*.

Our results show that integrating remote sensing techniques and expedited sampling methods allows rapid and effective monitoring of SAPS community composition, interactions, and species and community spatial distributions. More systematic monitoring data is needed to verify trends in distribution to advance explanations of the successional processes of these species, and to determine if the invasion is altering functionality at the ecosystem level.

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# An Analysis of the Seedbank at Joshua Tree National Park in Sites Invaded by Exotic Annual Grasses

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## Abstract

Exotic annual grasses and forbs are invading California's deserts and out-competing natives. Anthropogenic nitrogen deposition favors invaders by increasing resource availability. Invasive species have a negative impact on native species abundance in natural systems. Many desert species are adapted to using soil seed banks to insure long-term survival in an unpredictable environment. In this study, we examined how exotic invasions and nitrogen (N) deposition affect the soil seed bank. We examined four sites along a natural N deposition gradient in Joshua Tree National Park that have been part of a long-term N fertilization study (Allen *et al*. 2009). Soil cores were collected from control (0kg N/ha) and high (30kg N/ha) fertilized plots at each site. These soils were spread out in the greenhouse, watered liberally, and subsequent germination was recorded by species. This process was repeated until no further germination was observed. We compared the seed bank composition between fertilization treatments as well as between sites. There was no significant difference due to N fertilization in the seed bank, although grass cover was significantly high with N in field vegetation surveys. Exotic percent cover was inversely related to native percent cover and seed bank density. Examinations of soil seed banks can provide valuable information about the status of plant populations, invasions and potential for restoration.

## Introduction

California's ecosystems are plagued by invasive species. A relatively more recent victim is the southern California desert ecosystem. In contrast to many other invaded areas, invasion in the desert is a current and ongoing phenomenon. Invasive plants not only arrive in a new habitat, but proceed to establish and spread, often overtaking native vegetation. Biotic invasions can result in local extinctions, habitat alterations, changes in fire regime, altered soil nutrients and changes in local hydrology (Mack *et al* 2000). Anthropogenic disturbances can exacerbate the problem of invasive species by creating more invasible environments for them to inhabit. Studies show that the Los Angeles Basin may be subject to as much as 30-50 kg/ha/yr N through deposition (Fenn 2003, Allen *et al* in press). This creates a soil nutrient pulse that is a positive feedback for invasives. As urban expansion increases, California's deserts experience higher levels of N deposition. The desert is particularly sensitive to increased N levels and exotic invasive annual grasses, namely *Schismus* spp. and *Bromus rubens*, now dominate where natives once flourished (Brooks 2000).

Exotic invasions function at multiple life stages and scales. Invasions in California are coupled with N deposition, which further complicates competitive interactions. Seed production of individuals can be affected, which can alter the seed bank, leading to changes in seedling density and standing biomass. Native desert vegetation, in particular native annual forbs, is adapted to using a soil seed bank. Soil seed banks represent an ungerminated fraction of viable seed that is stored on or in the soil for future growing seasons. In harsh and often unpredictable desert systems, seed banks provide insurance that the species will continue even if established individuals perish (Olano 2005). The seed bank is also another way to monitor invasion and restoration potential in the desert because invasive annual grasses are not adapted to a long-lived seed bank.

In this study, we evaluate soil seed bank composition and relative species abundance in sites treated with 0 (control) or 30 kg/ha N fertilizer (high) in Joshua Tree National Park. Investigating the soil seed bank allows us to create a more precise picture of how invasion is affecting present species composition, as well as predicting the trajectory of change in the future.

## Methods

The soil seed bank comparison took place over four locations within Joshua Tree National Park (JTNP) in southern California, USA. The four sites are as follows: creosote bush scrub (CBS), low N deposition; CBS, high deposition; pinyon-juniper (PJ), low N deposition; PJ, high deposition. Nitrogen deposition was 3 and 5 kg N/ha/yr in the CBS sites and 6 and 12kg N/ha/yr in the PJ sites (Allen et al. 2009).

Each site contains ten block treatments of various N fertilization levels that were implemented for another ongoing (Allen et al. 2009). The plots used for this study were control (no additional N) and high N fertilized (30kg/ha) under either *Larrea tridentata* (creosote bush) or *Juniperus californica* (juniper), depending on the site. Eight soil cores 9x5 cm were taken from twenty plots at each site, ten control plots and ten high N fertilized plots, and combined into one composite sample per plot. Four samples were taken from the north side of the shrub and four from the south side. The samples were air dried and stored at 4˚C prior to germination. Composite samples were then spread out on trays in the greenhouse, watered, and stirred to stimulate germination. Seedlings were identified, recorded, and discarded as they appeared and the method was repeated until germination ceased.

## Results and Discussion

A one-way analysis of variance using JMP© was used to determine significant difference between treatments within sites for exotic grass, exotic forb, and native forb seeds/m². There was no significant difference ($\alpha=0.05$) between the north and south sides of shrubs, so the number of seedlings for each orientation was averaged to produce one sample per shrub. The data were calculated as number of seedlings per tray to seeds/m². There was no significant difference between treatments within any of the sites, although exotic grass cover was significantly higher with high nitrogen.

There were significant differences within N treatments among sites and between sites (see Table 1). Irrespective of N treatment, the PJ/low N site had significantly higher ($p< 0.0001$) native forb seed density than any other site. The exotic forb data was confounded by the fact that two of the sites had zero exotic forb germination in the greenhouse. However, exotic forbs have been recorded as present aboveground at every site.

| N Treatment | Site | Mean Exotic Grass seed/m² | Mean Exotic Forb Seed/m² | Mean Native Forb Seed/m² |
|---|---|---|---|---|
| Control | PJ/High N | 37.58 | 0** | 0.775 |
| Fertilized | PJ/High N | 41.85 | 0 | 0.38 |
| Control | PJ/Low N | 13.36 | 3.29 | 10.65** |
| Fertilized | PJ/Low N | 6.97** | 0.96 | 9.49** |
| Control | CBS/High N | 32.16 | 1.16* | 1.55* |
| Fertilized | CBS/High N | 38.75* | 0 | 0.77 |
| Control | CBS/Low N | 49.40 | 0** | 4.06 |
| Fertilized | CBS/Low N | 53.47 | 0.19 | 5.61* |

Table 1.

** denotes significance $\alpha$ = 0.0

Therefore, the significant difference between sites for exotic forb seeds/m² may be artificial.

The seed bank does not reflect the relatively small increase in percent cover of exotic grass due to N fertilization over three years, but it does demonstrate the different exotic seed densities for sites with different amounts of historic N deposition and different soil textures. The site with lowest N deposition also had the lowest soil rock percentage. Finer textured soil can be more susceptible to invasion, as demonstrated by the higher density exotic grass seed bank in the other, rockier, sites. Furthermore, the seed bank demonstrates that less invaded sites tend to have a higher density native seed bank. This suggests that exotic invasion can influence seed bank dynamics; although we cannot be sure to what extent this is occurring.

Examining the seed bank in a system affected by exotic invasion can provide information on long-term invasion effects as well as both active and passive restoration potential at a given site. In this study, a nitrogen effect was included to understand how increased nitrogen deposition can influence exotic invasion and seed bank dynamics. Although we did not find significant differences between treatments within sites, we were able to elicit important trends between sites that may affect seed banking, such as historic N deposition levels, soil texture and rockiness, and the magnitude of invasion. Furthermore, due to the strict germination requirements commonly imposed on desert species, it is unlikely that the germination observed in the greenhouse represents full extent of the soil seed bank at these sites. Additional treatments to induce germination would generate more information about the number and identity of seeds in the soil. There are many factors that influence seed output and subsequent additions to the seed bank and further research is needed to fully comprehend its role in exotic invasions.

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## Patterns of Change in Water Hyacinth Distribution in the Sacramento-San Joaquin Delta

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### Abstract

Water hyacinth (*Eichornia crassipes*), known to be the fastest growing macrophyte in the world, has been recorded in the Sacramento-San Joaquin Delta since 1904. By 1984, it already covered 506 hectares or 22% of the waterways in the Delta resulting in huge economic and ecological costs. Through analysis of hyperspectral HyMap imagery flown over the Delta since 2003, we have been successful in mapping water hyacinth with over 80% accuracy. Because of the extensive efforts to control water hyacinth distribution combined with unfavorable environmental conditions, it has steadily decreased in cover over the past decade and in 2007, only 187 ha of hyacinth were mapped across the entire Delta. Water hyacinth mats provide poorer habitat to aquatic communities including native fish as compared to native species like pennywort and primrose hence it is important to consider turnover between these species. This study details a simple, robust and effective method to map floating emergent species including water hyacinth and study the turnover between them.

### Introduction

Water hyacinth (*Eichornia crassipes*), native to Brazil has successfully invaded almost every region in the world that is suitable for its growth including China, India, Indo-China, Japan, Siam, S. Africa, Europe and the United States (Penfound and Earle 1948). It has the highest growth rate of any saltwater, freshwater or terrestrial macrophyte. It can double in patch size every two weeks clogging navigation channels, obstructing drainage in agricultural fields, impeding access to banks of lakes and leading to enormous economic and ecological costs (Toft *et al*. 2003, Opande *et al*. 2004). Physiologically, it is primarily a freshwater plant, greatly affected by freshwater inflows that can change water salinity (Penfound and Earle 1948). Temperatures over 34˚C for many successive days prove fatal for hyacinth. Additionally, it requires full sunlight for at least six hours a day for optimal growth (Williams et al. 2005). Under conditions of frost, all above water canopy dies off but the rhizomes survive under water and the plants regenerate during the growing season. However, consecutive frost days can kill the rhizomes and the plant fails to regenerate (Penfound and Earle 1948). Northern California climate is no stranger to either frost or heat waves and both extreme conditions can reduce hyacinth abundance.

The study area, the Sacramento-San Joaquin Delta (Figure 1) has over 234 exotic species with an increasing rate of invasion and is considered one of the most invaded estuaries in the world (Cohen and Carlton 1998). Water hyacinth was first recorded in the United States in 1884 in New Orleans and had reached the Sacramento River by 1904. By 1984, it already covered 506 hectares in the Delta (Finlayson 1983). It has been steadily decreasing in cover over the past decade and in 2007, only 187 ha of hyacinth were mapped across the entire Delta (Ustin *et al*. 2008). However, if it is not totally eradicated, it can spread from nursery sites and resurge in cover if conditions become favorable again. Studies have shown that oxygen levels below water hyacinth mats are lower than that below native

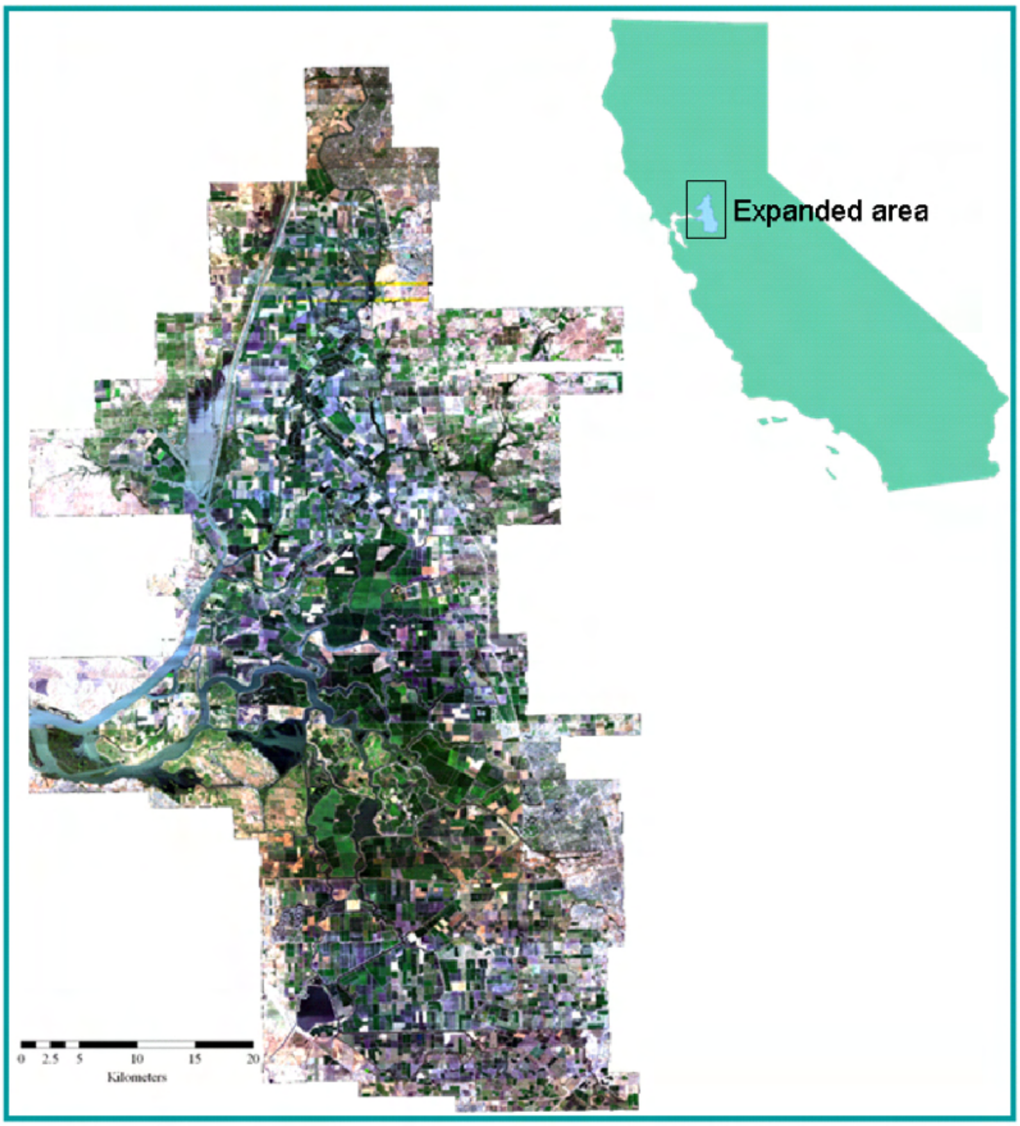


Figure 1

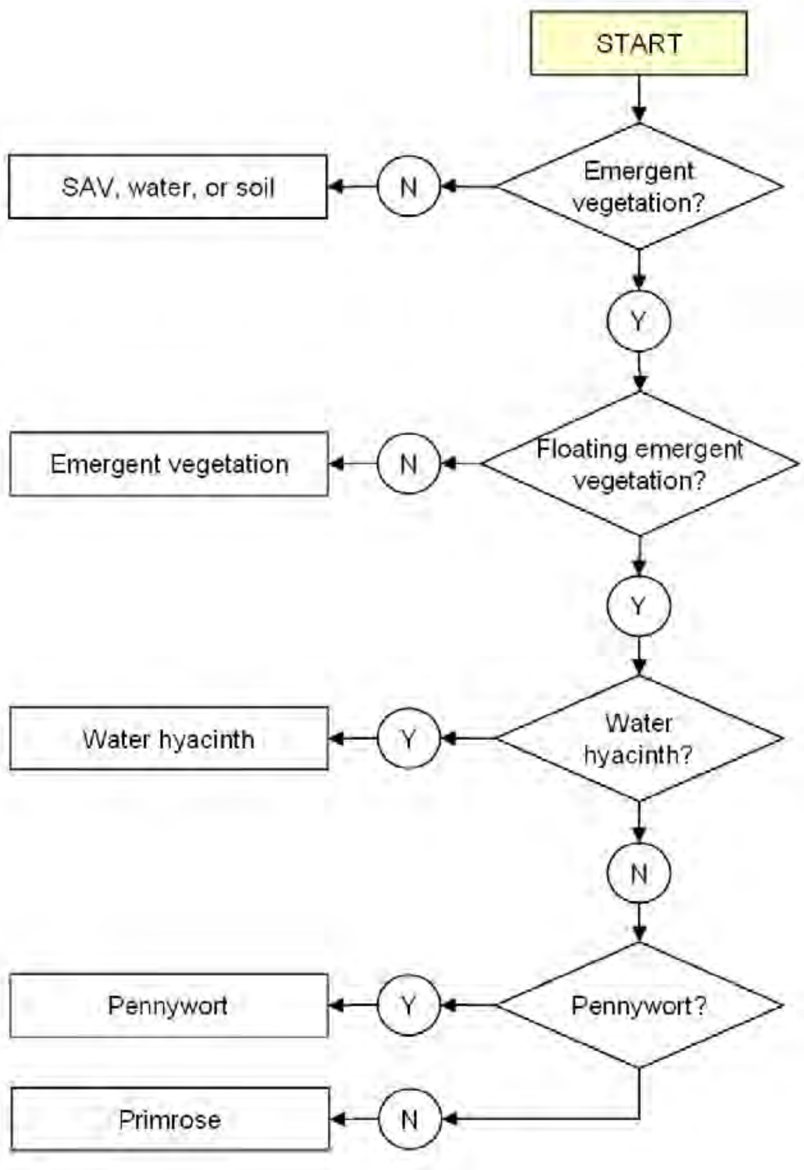


Figure 2

species' mats. Communities of invertebrates and fishes supported by native pennywort (*Hydrocotyle umbellate*) mats are richer and have a higher percentage of native species that those sheltered in hyacinth mats (Simenstad *et al*. 1999). Thus a simple analysis of hyacinth presence-absence is not sufficient to provide an accurate assessment of ecosystem health. The turnover between these three floating emergent species is an important marker of future trends. Hence this study looks at simple and robust methodologies that translate across wide spatial and temporal domains to first differentiate floating emergent species from other land covers and then to discriminate between the three floating species.

## Methods

The imagery extent for the years 2004, 2005, 2006 and 2007 is shown in Figure 1. The study area was flown by HyVista Corp. to obtain imagery at 3m pixel resolution over the Delta. Concurrent with the image collection, GPS (Global Positioning System) data were collected in the field every year with greater than one m accuracy. Data points were collected every year for patches of emergent vegetation and water along with patch and environmental attributes. Target species included water hyacinth, pennywort, primrose (*Ludwigia hexapelata*), tule (*Schoenoplectus acutus*), common reed (*Phragmites australis*), giant reed (*Arundo donax*) and cattails (*Typha* spp.), and many riparian species.

Five sets of files with input variables were created from the original images to be used for the classification algorithm (see Hestir *et al*. 2008). Each of these variables highlights specific properties of the target species, and was used together with statistical techniques like ANOVA to perform the classification. Water hyacinth, primrose and pennywort can each have a wide range of morphological characteristics like presence/absence of flowers, shape of leaves, mat thickness, etc; all of which affect the spectral signature of the species. Hence the broad use of variables that stress physiological differences between species and can be adjusted every year help in the development of a strategy that works every year. Figure 2 shows the sequence in which the different groups were separated. First all emergent vegetation was separated from submerged aquatic vegetation (SAV), water and soil. Next, emergent vegetation was separated into floating emergent species (hyacinth, pennywort and primrose) and emergent species (tule, cattails and reeds). While hyacinth is more distinct in its spectral signature from pennywort and primrose, the latter two are not as different from each other and are more difficult to separate. Hence the next step separated hyacinth from the other two floating species and finally, pennywort and primrose were separated in the last step. Map accuracies were assessed using producer's and user's accuracies.

## Results and Discussion

Classifications of June 2004, 2005 and 2007 imagery indicated the presence of 308 ha of water hyacinth in 2004, 375 ha in 2006 and only 187 ha in 2007. Total floating emergent vegetation area in 2004 was 1807 ha, 1041 ha in 2006 and 336 ha in 2007. Table 1 shows the user's and producer's accuracies for each class and overall accuracy and Kappa coefficients for each year. The overall accuracies were over 90% for 2004 and 2007 and 88% for 2006. Primrose accuracy was the lowest as this is the most difficult class to separate.

Table 2 lists the variables that were useful in separating out the three groups in each year. Figure 3 illustrates the separation between groups for two variables. While the best variable for separating groups was different for each year, there were common differences observed between classes across all three years demonstrating the robustness of this technique and its ability to translate across space and time. The next important step in this study is to evaluate the change in total cover of these species and the turnover among them and relate the changes to environmental, local and regional influences in the Delta.

| CLASSES | YEAR OF ANALYSIS | | | | | |
|---|---|---|---|---|---|---|
| | June 2004 | | June 2006 | | June 20007 | |
| | Producer's | User's | Producer's | User's | Producer's | User's |
| Emergent vegetation | 99.82 | 98.91 | 98.42 | 97.27 | 92.13 | 92.82 |
| Water hyacinth | 94.73 | 98.79 | 90.19 | 89.98 | 95.38 | 100.00 |
| Pennywort | 93.46 | 92.53 | 89.07 | 85.06 | 92.48 | 96.60 |
| Primrose | 84.88 | 75.00 | 76.94 | 82.59 | 94.86 | 85.76 |
| All Classes | 95.08, Kappa: 0.93 | | 88.46, Kappa: 0.83 | | 93.80, Kappa: 0.92 | |

Table 1

Producer's, user's and overall accuracies and Kappa coefficients for all three years.

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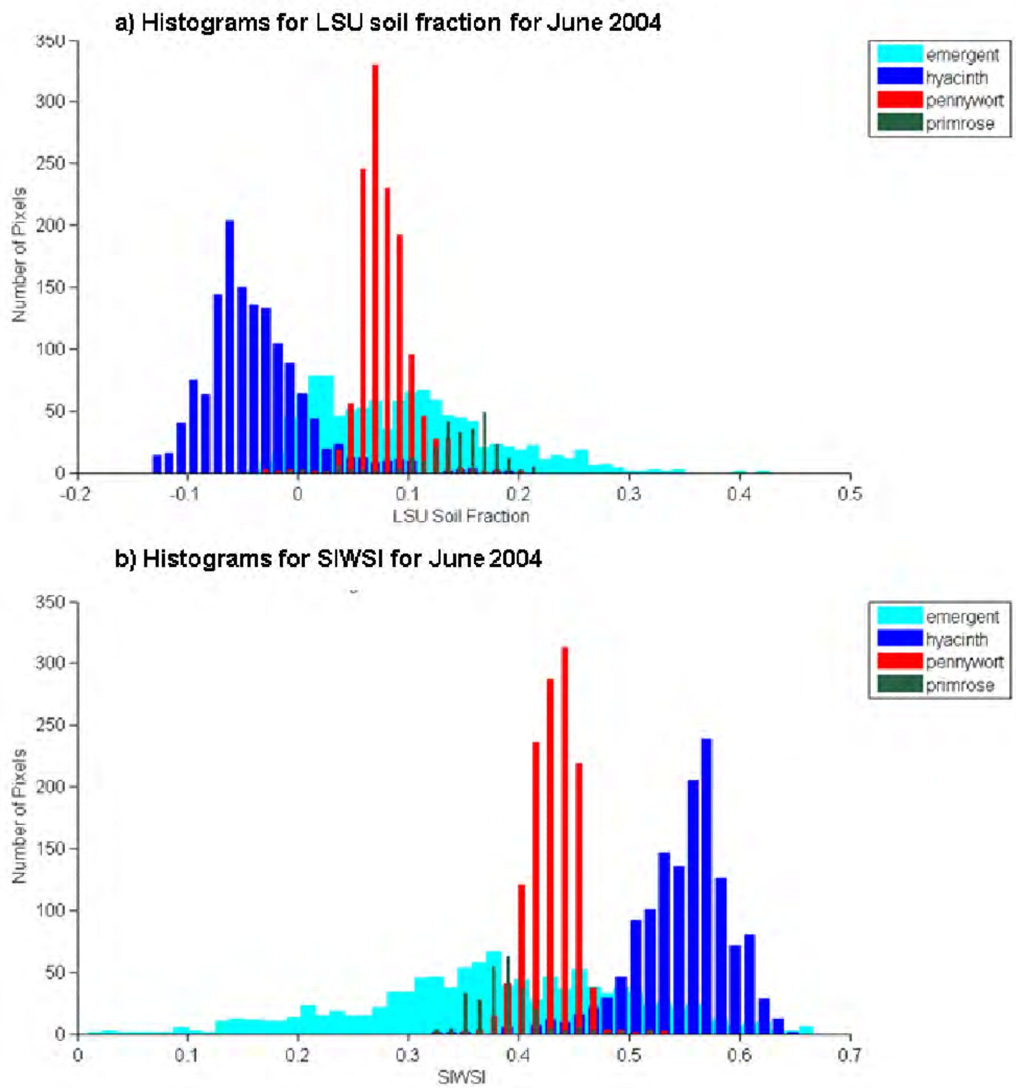
| **Groups to be differentiated** | **Year of Analysis** | | |
|---|---|---|---|
| | **June 2004** | **June 2006** | **June 2007** |
| floating emergent vs. emergent | *LSU vegetation fraction*<br>NIR average reflectance<br>Red edge index | *NIR average reflectance*<br>LSU vegetation reflectance | *NIR average reflectance*<br>NIR slope difference |
| water hyacinth vs. pennywort/primrose | *SIWSI*<br>SWIR2 average reflectance<br>LSU soil fraction | *SWIR2 average reflectance*<br>SWIR1 average reflectance | *SAM exposed algae*<br>Continuum removal 2<br>SWIR2 average reflectance |
| pennywort vs. primrose | *LSU soil fraction*<br>SWIR2 average reflectance | *Cellulose absorption index* | *Red edge index*<br>Green reflectance |

Table 2

Differentiating input characteristics between groups. Italicized inputs were the ones used in the decision tree.

Figure 2


a) Histograms for LSU soil fraction for June 2004
Number of Pixels
LSU Soil Fraction
emergent
hyacinth
pennywort
primrose
b) Histograms for SIWSI for June 2004
Number of Pixels
SIWSI
emergent
hyacinth
pennywort
primrose

# Contributed Posters

## Results from the Use of a Novel Method, HydroMechanical Obliteration, at the Golden Gate National Recreation Area in West Marin

*Maria Alvarez*, Golden Gate National Recreation Area, CA*

*Cameron Colson and Maria Morales, CAMCO, CA*

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HydroMechanical Obliteration (H_M_O), a new method, was used on six invasive plant species in Marin County, California at the Golden Gate National Recreation Area (GGNRA). In 2006, treatment of Harding grass (Phalaris aquatica) was funded by a grant from the National Fish and Wildlife Foundation for the Marin Municipal Water District, Marin State Parks, Audubon Canyon Ranch and the GGNRA. The National Park Service funded the treatment of the additional five species. H_M_O uses a water spray at high PSI levels for the precision removal of vegetation, producing an on-site mulch. Harding grass received four treatments over 18 months resulting in 100% reduction in seed head production. Cape-ivy (*Delairea odorata*) and English ivy (*Hedera sp*.) both had significant reductions with a single treatment. H_M_O was used successfully as a follow-up to a prior mechanical removal for Cape–ivy and panic veldt grass (*Ehrharta erecta*). On jubata grass (*Cortaderia jubata*) 50% of the smaller plants were removed after one treatment; larger plants needed three to four treatments over twelve months. Larger specimens such as mature French Broom (*Genista monspessulana*) growing among compacted rock was rapidly pulled and hauled off-site. We found H_M_O a beneficial and cost-effective addition to our IPM toolbox.

## San Luis Rey River Flood Risk Management Area Giant Reed Eradication

*Raquel Atik*, Italia Gray and Peter Tomsovic, RECON Environmental, San Diego, CA*

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The U.S. Army Corps of Engineers (USACE) in collaboration with RECON Environmental, Inc. implemented a giant reed (*Arundo donax*) eradication program within the San Luis Rey River Flood Risk Management Area (SLRRFRM), City of Oceanside, California. Giant reed is detrimental to native riverine ecosystems because it forms dense, monotypic stands that displace native vegetation, reduce groundwater availability; alter stream flow and increase potential for wildfires and flood risk. The SLRRFRM Project goal is to increase flood conveyance in the channel and maintain habitat within the channel and detention ponds for resident endangered species and their critical habitat. The project has been permitted by the US Fish and Wildlife Service, the Regional Water Quality Control Board, the California Department of Fish and Game, the National Marine Fisheries Service, and the California Coastal Commission. Giant reed control activities consisted of foliar application of glyphosate herbicide in the fall, allowing the herbicide to translocate to its rhizomes, and then mowing the large dead stands in late winter and early spring. Approximately 40 acres of giant reed were treated and subsequently mowed. This treatment method has proven very effective, with trials having almost 100% efficacy when foliar applications occur in the appropriate season. Although fall foliar applications are most effective, repeat treatments are necessary for complete giant reed eradication. Although a newly approved imazapyr-based herbicide has proven very effective in treating giant reed during spring months, repeat treatments are pending regulatory agency approval for work during the breeding season of sensitive avian species.

## Invasive Aquatic Weeds: Implications for Mosquito and Vector Management Activities

*Charles E Blair, MD*, Trustee, Mosquito and Vector Management District of Santa Barbara County (MVMDSBC) and active member of Cal-IPC and CNPS , Lompoc, Ca. *blairce@verizon.net*

### Introduction

The adverse effects of invasive aquatic and riparian weeds on water quality; hydrology, native plant communities, and wildlife habitat have been discussed at many Invasive Plant and General Botanic meetings. Their consequences for mosquito control efforts, public health and nuisance problems, while implied, could be better articulated. As a life-long general naturalist, a retired surgeon, a trustee on Mosquito and Vector Management District of Santa Barbara County (MVMDSBC) and a member of the Southern California Vector Control Environmental Taskforce (SCVET), I have become increasingly aware of these relationships. This poster will present some of these relationships and highlight collaborative activities between vector and weed control agencies.

### Integrated Pest Management in Relation to Mosquito Control

Concentrating on larvae and pupae is the first-line approach. Free-flowing waterways discourage mosquito breeding. Native predators in natural habitats and introduced predators, i.e. mosquito fish, *Gambusia affinis,* in artificial ones are mainstays. Biorational larvicides, such as *Bacillus thuringiensis* ssp. *israelensis* (Bti), *Bacillus sphaericus* (Bsp), and maturation inhibitors such as IGR/JHA–Methoprene serve to reduce larvae, and facilitate the action of predators. These are distributed as granules or briquettes.

#### *Freshwater Invasives*

Water hyacinth, *Eichhnorina crassipes,* hydrilla, *Hydrilla verticillata,* Eurasian watermilfoil (*Myriophyllum spicatum*) and especially water evening-primrose, Ludwigia spp. are among the principal problem plants. These invasives reduce circulation and inhibit predators. Water Evening-primrose infestations can be so dense that granules and briquettes cannot reach the water. Two studies presented at the 2008 MVCAC Conference showed reduction of predation by both introduced native fish (Henke 2008) and mosquito fish (Popko 2008).

#### *Saltmarsh Invasives*

**In estuarine habitats,** smooth cordgrass, *Spartina* spp., especially the hybrid S. *densiflora x foliosa* (Ayres et al. 2007) invade near-shore saltmarshes displacing native species, invade deeper waters, and inhibit tidal fluctuation leaving slack-water areas where saltmarsh mosquitoes, *Aedes spp.* proliferate.  These are far-flying, aggressive day biters, some of which can carry pathogens, such as West Nile Virus.

#### *The San Francisco Estuary Invasive Spartina Project; A Successful Collaboration*

The Invasive Spartina Project is a coordinated regional effort among local, state and federal organizations dedicated to preserving California's extraordinary coastal biological resources through the elimination of introduced species of *Spartina* (cordgrass). The highly effective synergy between the San Mateo County Mosquito Abatement District (SMCMAD) and regional Weed Management Areas can serve as a model for similar efforts elsewhere. (San Francisco Bay Spartina Project, Olofson 2000)

Several thousand acres of *Spartina alterniflora x foliosa* were successfully eliminated, chiefly from abandoned salt evaporation ponds as well as open bay waters from Candlestick Park to the San Mateo – Santa Clara County line. There is significant re-growth of salt marsh natives, including pickleweed, *Frankenia*, and native cordgrass.

Imaprazyr was recently approved for aquatic use in California. It is much more effective than glyphosate (Rodeo) on *Spartina*.(Kilbride and Paveglio 2001) Activities were timed to avoid nesting clapper rails and other wildlife. Projects were done in a mosaic pattern allowing wildlife to find suitable nesting sites, and encourage re-growth of native vegetation. (Counts 2007)

These efforts have greatly improved the wildlife habitat, enhanced the aesthetic qualities, facilitated control of mosquitoes with less pesticide use, and had good public acceptance. This synergy can serve as an example the efficacy of collaborative activities elsewhere.

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## Lake Tahoe Aquatic Invasive Species Pilot Project – Measuring and Adapting Standard Methods of Control for Use in an Alpine Environment


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*Doug Freeland, Aquatic Consulting Evaluation, Spirit Lake, ID*

*Giovanni Caterino, Tahoe Divers Conservancy, Carnelian Bay, CA pcaterino@mac.com*


Lake Tahoe is designated an *Outstanding National Resource Water* due to its extraordinary clarity. The Tahoe Divers Conservancy (TDC), a volunteer nonprofit organization, in partnership with the Tahoe Resource Conservation District (TRCD), The Tahoe Regional Planning Agency (TRPA), California State Lands Commission (CSLC), and California State Department of Parks and Recreation (CSDPR) is conducting a three-year project to remove the invasive Eurasian Watermilfoil (*Myriophyllum spicatum*) from Emerald Bay (A California State Underwater Park) and Ski Run beach in South Lake Tahoe, California. The Bureau of Reclaimation (BOR) funds this project. Intended outcome and critical component of the project is the development of an Invasive Aquatic Plant Monitoring Protocol which will determine the effectiveness of adapting standard removal techniques to Lake Tahoe. The purpose of the protocol is to provide a mechanism to record and inventory invasive aquatic plant species infestations via diver surveys, provide an accurate record of removal efforts in the project areas and provide follow-up monitoring to sites where invasive aquatic plant species are removed to determine the efficacy of the treated areas. Because water quality standards restrict *any* chemical use in the waters of Lake Tahoe, the standard methods of treatment/removal of aquatic weeds in Lake Tahoe to be assessed will only include diver-assisted suction removal, involving divers hand pulling the plants by the roots to feed into a suction hose attached to a small dredge and bottom barriers, which is a cloth or screen that covers the bottom surface to prevent light and smothers the plants. While both these methods have great promise for effective removal and control at Lake Tahoe, the process must be monitored for effectiveness and environmental impacts, such as habitat disruption and elevated turbidity.

## Hybridization Between Invasive and Native Blackberries (*Rubus*) in California

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### Abstract

Hybridization between native and introduced species has the potential to generate highly invasive populations of weeds, as most infamously demonstrated by *Spartina*. The genus *Rubus* includes a number of invasive plants, in particular Himalayan blackberry (*R. armeniacus*), an invasive weed of California and the Pacific Northwest as well as elsewhere in the world. Given the large number of species in this genus and the morphological variation within species, *Rubus* hybrids and introgressed individuals may be difficult to identify visually. Here we use molecular genetic tools to demonstrate natural hybridization of the native Pacific blackberry (*R. ursinus*) with both the invasive *R. armeniacus* and the introduced Pennsylvania blackberry (*R. pensilvanicus*) in California. We are currently investigating whether this hybridization has led to the introgression of non-native genetic material into *R. ursinus*. Future studies will investigate the potential of hybrid *Rubus* to contribute to the invasive species problem in California, or alternatively to harm native *R. ursinus* populations through outbreeding depression.

### Introduction

Biological invasion is often facilitated by rapid adaptive evolution. This provides opportunity to use genetic and genomic tools to understand the basis of invasiveness, since the invasive species may be compared to very closely related non-invasives (Prentis *et al*., 2008; Schierenbeck and Ainouche, 2006; Lee, 2002). Hybridization provides several mechanisms by which invasiveness can evolve in plants: 1) hybrid vigor that is maintained through asexual reproduction, 2) novel combinations of genetic material from the parental species, 3) increased genetic variation that allows local adaptation, and 4) introduction of normally functioning genes so that selection can eliminate harmful mutations (Ellstrand and Schierenbeck, 2000).

We have chosen *Rubus* (blackberries and raspberries; Rosaceae) as a genus in which to study the phenomenon of hybridization stimulating invasiveness. *Rubus* includes eleven noxious weeds in the United States alone (USDA Plants Database) and these are taxonomically well distributed within the genus. In particular, Himalayan blackberry (*R. armeniacus* Focke = *R. discolor* Weihe & Nees and *R. procerus* Mueller), a naturalized cultivar originating in Germany (Kent 1988), is highly invasive in California and the Pacific Northwest (Cal-IPC invasive plant inventory; Washington State Noxious Weed Control Board). *Rubus* also has a history of evolution through hybridization (Weber, 1996). Since there are seven native and at least four naturalized introduced species of *Rubus* in California (Ertter, 1993), it is possible that hybridization could stimulate the evolution of new invasive forms.

This paper describes a preliminary study in which we identify first-generation hybrids of native *Rubus* with introduced *Rubus* in California. Future studies will assess the invasive potential of hybrids and the degree to which they have sexually recombined with the parent species.

## Materials and Methods

In 2007 and 2008 we collected leaf tissue from 324 *Rubus* individuals at 17 sites across Central and Northern California. We collected voucher specimens of each species or type at each site in 2008, and are storing them at the UC Davis Center for Plant Diversity. We have also been given a sample of 28 individuals from sites in Southern California and four specimens from the Brooklyn Botanical Gardens. Our sample set is primarily *R. armeniacus* and *R. ursinus* (Pacific blackberry, native), as these are the species most commonly found in California. Ten other species and cultivars were also collected.

For genetic analysis, we ran six microsatellites from Graham *et al*. (2002) and Lopes *et al*. (2006). Across the sample set, 230 alleles were discovered within these six loci, most of the diversity being in *R. ursinus*. Hybrids were identified by genetic distance using Principal Coordinate Analysis, and were confirmed by visual inspection of genotypes. To determine the maternal (seed) parents of hybrids, we developed and ran two chloroplast markers on our sample.

## Results

We saw very little genetic diversity in *R. armeniacus*, and what variation there was originated from mutation rather than sexual recombination. This is consistent with its asexual seed production (apomixis) and its introduction as a cultivar. In contrast, *R. ursinus* showed considerable genetic diversity in both the nuclear (in the cell nucleus) and chloroplast (seed lineage) genomes. This is expected, because *R. ursinus* was sampled in its native range, where it has had millions of years to accumulate genetic diversity. *R. ursinus* is also dioecious (every plant is either male or female, ensuring outcrossing), which is consistent with the low amount of geographic structuring of the nuclear and chloroplast genotypes.

Two genetically distinct *R. ursinus* x *armeniacus* hybrids were identified at Caswell Memorial State Park. *R. ursinus* was the maternal parent of both. Both parental species are present at the site, although *R. armeniacus* is a target of eradication. Characters such as leaf shape and color, prickle number and morphology, and stem cross section were intermediate between the two species. First-year vegetative canes were growing vigorously when we visited.

One *R. ursinus* x *pensilvanicus* hybrid was identified at Bidwell Park. *R. ursinus* was the maternal parent. *R. pensilvanicus* is an introduced plant from the Eastern United States, but is not common in Northern California. *R. pensilvanicus* was growing in Bidwell Park near the hybrid, but was not found at any of our other sites. *R. ursinus* was present at the site but not growing as vigorously as *R. pensilvanicus* or the hybrid. Both *R. pensilvanicus* and the hybrid were producing fruit when we visited in late May 2008. There was great variation in leaf morphology even within one cane of the hybrid; leaves had three to seven leaflets, which could be arranged in a pinnate or palmate manner. Stem and prickle morphology was intermediate between the two parental species, while the seven leaflets was a transgressive trait.

## Discussion

First generation hybrids were fairly uncommon in our data set (about 1% of individuals sampled), possibly due to brief overlap of flowering times of parental species, pollinator preference, low interspecies fertility, or other factors. However, the number of molecular markers we used was not sufficient to detect later generation hybrids and backcrosses. Given the high morphological diversity within *Rubus* species, backcrossed individuals might not be obvious from visual inspection either. As we add markers and use more sophisticated software for hybrid detection, it is possible that we will find introduced genetic material introgressing into native *Rubus* species or vice versa. This could cause reduced fitness in *R. ursinus* populations if some of its genes are incompatible with those of other species, or novel gene combinations could cause increased fitness and potential for invasiveness. We will test for these possibilities using common garden experiments. Ultimately we plan to measure gene expression differences between closely related invasive and non-invasive species of *Rubus*, and determine whether hybrids found in California more closely match the invasive or non-invasive profile. This will not only help to prioritize the management of hybrid *Rubus*, but will also give insight into the genetic basis of invasiveness so that it may be predicted in other species.


### Acknowledgments

Thanks to Caswell Memorial State Park, Cosumnes River Preserve, Coal Oil Point Reserve, Paradise Reserve, and Sedgwick Reserve for permission to sample and assistance with collection. Dr. Lawrence Alice of Western Kentucky University kindly assisted with identification of species through photographs and DNA sequences. This work was supported in part by a UC Davis Plant Sciences Departmental Research Assistantship.


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## The Evolution of Artichoke Thistle (*Cynara cardunculus*) Data Management at Camp Pendleton, CA (1984-present) and Application of Data to Model


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### Abstract

Artichoke thistle is considered to be one of Marine Corps Base Camp Pendleton's "Ten Most Wanted Weeds." In addition to being non-native and invasive, spiny artichoke thistle also directly impairs military operations. Camp Pendleton's artichoke thistle program is unique in the respects of its duration (24 years), consistency of the data being collected by one contractor and its success in terms of reducing artichoke thistle numbers. With the advent of GIS, record keeping in the artichoke thistle control program has evolved and improved in quality.

The historic data management methods (hard copy maps) combined with GIS has yielded specific conclusions. First, artichoke thistle populations have decreased considerably base-wide since 1984. Second, mapping large monocultures of thistle is very different than mapping isolated individuals characteristic of today's trace densities. Program data management techniques and results of a model created using artichoke thistle extent data are presented here.


### Introduction

Throughout the 24-year artichoke thistle control program, extensive data has been collected on artichoke thistle extent and density on Marine Corps Base Camp Pendleton, California. Data management methods on Camp Pendleton have adapted to new technology and reduction in thistle numbers. The evolution of data collection methods and how data has been used in model creation are described here.

### Methods

Data management for weed control programs on Camp Pendleton is a considerable challenge because of the base's size (~125,000 acres), and hence, must be done in an efficient manner. In the early days of the artichoke thistle program, thistle patch extents were hand-drawn on paper maps; today population extent delineations are more Geographic Information System (GIS) based. Thistle percent cover used to be dead reckoned, which was relatively easy to do because discrete patches of thistle monocultures existed on base. Later, thistle percent cover was calculated using a formula incorporating individual artichoke thistle plant counts. Today, Camp Pendleton is moving towards an era of comparing photos (showing thistle patches quantitatively measured for percent cover) of thistle density classes to on-site field observations to determine thistle percent cover. With the advent of lower thistle populations (and hence lower thistle visibility) resulting from treatment, it has become necessary to use GPS units to re-locate thistle patches.

Some of the base's artichoke thistle extent data (1984-1996) has been incorporated into a GIS-based spatial raster model to predict areas with high artichoke thistle density (IGIS Technologies, Inc. 2005). Model formation involved creating statistical data profiles. Statistical data profiles of habitat characteristic types (for example, in regards to the vegetation habitat characteristic, types are grassland, oak woodland, coastal sage scrub, etc.) were created by examining the overlap between artichoke thistle extent GIS layers that overlapped types in habitat characteristic GIS layers. Distances between thistle extents and road and streams were calculated. The overlaps and distances were analyzed and a ranking system was developed for habitat characteristic types. Another aspect of the model, weights, were based on statistical data profiles and *expert consultation and were assigned to habitat characteristics used in the model.

## Results and Discussion

Camp Pendleton's artichoke thistle control program is an interesting case study due to the long program duration, the extensive data set, the consistency brought about by using one contractor and the success in terms of reducing artichoke thistle numbers. The decrease in artichoke thistle density and extent on Camp Pendleton since 1984 is apparent. In 2007, 98% of artichoke thistle areas had <1% density.

According to the data profile results, artichoke thistle is most likely to grow on Gaviota fine sandy loam or Las Flores loamy fine sand, near roads, from 201-600 feet in elevation, between 11-25% slope and in a grasslands vegetation type on Camp Pendleton. Weights were assigned to various habitat characteristics as follows in the model: soil (20%), distance from roads (20%), elevation (13%), slope (12%), vegetation (10%), aspect (3%) and distance from streams (2%).

It was determined that some areas of Camp Pendleton may be vulnerable to artichoke thistle invasion, and should be watched closely. In the future, the model will be tested and fine-tuned using post-1996 information. The artichoke thistle model is a pilot model, and in the future, similar models for other non-native invasive species may be used as adaptive weed management tools on Camp Pendleton.

*Expert Opinion. The following non-native invasive plant professionals were consulted to help determine model weights: Dr. Carl Bell, Regional Advisor, Invasive Plants, SDSU Extension; Todd Easley, Camp Pendleton; Dr. Ginger White and Robin Marushia, Dr. Holt Lab, UC-Riverside

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## Ludwigia Control as a Precursor to Restoration: Progress and Challenges

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The Laguna de Santa Rosa Foundation has completed a three year effort to control *Ludwigia* sp. (creeping water primrose) in five miles of channel and one hundred acres of perennially inundated floodplain in Sonoma County, CA. Methods included application of herbicide followed by mechanical removal where feasible. The results varied widely with rapid regrowth in shallow channels and areas where complete removal was not possible. Deeper channels experienced far slower re-growth. Future maintenance will be required until more effective methods of control are identified and underlying conditions favoring *Ludwigia* are addressed at both a watershed and site specific scale. This should factor into but not preclude restoration planning and implementation.

## Sinapsis Alba Seed Meal as a Pre-Emergent Control for French Broom (*Genista Monspessulana*) Seedlings

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The authors tested *Sinapsis alba* pressed seed meal as a pre-emergent inhibitor of French broom seedlings in 2007-2008 at Quail Hollow County Park. S. alba seed meal is known to contain 4-hydroxybenzyl isothiocyanate which releases a quinone that hydrolyzes in soil to form SCN-, a known bioherbicide. The meal was applied by broadcasting it on the surface of the soil of the 4 m by 4 m blocks at a rate of approximately 8.8 kg of SCN-/ha. A significant decrease of broom seedlings was observed in treated plots compared to controls ($F=14.2$, $P=0.001$). While there were no significant differences found in quality or quantity of soil fauna between treated and untreated blocks, there was a slightly elevated (6% higher) level of nitrogen observed in treated blocks. While this concentration of *S. alba* seed did inhibit seedling germination over one eight month germination season, it did not stop germination of all French broom seedlings limiting its usefulness as a control agent at this level of application.

## "A" Rated Weeds on Display: CDFA's Internet Mapping Website

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California Department of Food and Agriculture's (CDFA) Noxious Weed Internet Mapping Service (IMS) site is a collection of data consolidation from a long list of contributors. The intended purpose of these IMS sites is to provide information and gather more information about

"A" Rated Weeds throughout California. This project started in 1996 with the creation of the Aweed Database by Integrated Pest Control Branch. Collection of the data has occurred over the years from historic records, County Agriculture Departments, Weed Management Areas, US Forest Service, Bureau Land Management, and CDFA personal. This database maintains data about the centroids of populations of "A" Rated Weeds. There are two sites, a public site and a private site. The public site displays the database information in the MTR grid and gives general information. The private site shows the centroids of populations and details about the populations. The IMS sites are an ongoing project of CDFA and updated regularly.

## Mechanical Control Coupled with Native Species Planting as a Cost-Effective Method of Controlling Himalayan Blackberry

*Nick Pacini, River Partners, Chico, CA. npacini@riverpartners.org*

River Partners is conducting an ecological enhancement project as part of the riparian restoration taking place at the Bear River Setback Levee Project in Yuba and Sutter counties. The Three Rivers Levee Improvement Authority (TRLIA) is setting back the levee in order to enhance flood safety along the lower Feather River. The enhancement project includes control of numerous Himalayan blackberry (*Rubus discolor*) stands that have invaded an area of remnant vegetation. We mowed the stand using a Bobcat forestry cutter in March of 2008. The cutter proved to be a very efficient means of removing the blackberry brambles in small areas (<one acre) that also contain desirable native vegetation including trees and large shrubs. In a relatively small amount of time, we were able to clear many large stands, limited only by topography. We followed with two months of treating resprouts with Garlon® (triclopyr). We then planted a diverse palette of native vegetation including box elder (*Acer negundo*), Oregon ash (*Fraxinus latifolia*), virgin's bower (*Clematis ligusticifolia*) and the native California blackberry (*Rubus ursinus*). In the fall and winter months we will be planting willow cuttings and an herbaceous understory. Early observations reveal that native recruits such as Santa Barbara sedge (*Carex barbarae*) are already colonizing sites once dominated by the blackberry. We anticipate that following up the mowing with aggressive resprout control and active planting, native vegetation will become established and out-compete the Himalayan blackberry.

## Controlling an Invasive Grass in a Grassland Setting – Harding Grass Control in the Bald Hills of Redwood National and State Parks

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Redwood National and State Parks is using Aquamaster to treat a Harding grass (*Phalaris aquatica*) infestation in the coastal prairies of the Bald Hills. This project is funded by the National Park Service, and California Department of Food and Agriculture. Harding grass has invaded over 40 acres of coastal prairie, with two main population centers and many pioneers scattered amongst 1200 acres of grassland. After two years of small scale treatments and one year of more aggressive treatment, over 30 acres of Harding grass will have been treated with a foliar application of Aquamaster. Monitoring plots have been installed to assess treatment effects. This poster will discuss initial results, lessons learned and plans for the future.

## Invasive Plant *Arundo donax:* Mapping and Prioritizing Its Eradication in the Bay-Delta Region of Northern California

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The invasive plant *Arundo donax* has become widespread in California. In Southern California some riparian habitat has been reduced to monotypic stands and eradication has been costly. In Northern California, Arundo infestations are less widespread. However, eradication began later and has occurred in a piecemeal fashion as individual organizations fight local infestations. It is generally accepted by the invasive plant control community that there insufficient funding to eradicate all problem weeds and control efforts must be strategically focused. To support this work, Team Arundo del Norte, a collaboration of organizations working on the control of Arundo, has completed a map of Arundo observations in the San Francisco Bay and Delta Regions and developed recommended eradication priorities based on the value of the threatened habitat. Available mapping data from 21 organizations was consolidated, critical gaps were field mapped and all data combined into a single GIS layer. This data is available on BIOS and CRISIS Maps. To identify eradication priorities, habitat suitability data for a suite of representative riparian species were combined with federal and state threat listings to derive a multi-species conservation value. At a given location, this index suggests the eradication priority for any threatening Arundo. This ranking of Arundo sites will be useful to weed managers, who can combine the information and maps with local expert opinion to assist in development of their weed control strategy.

## Adaptation and Evaluation of “Double Tent” Solar Heating for Eradicating Weed Seeds in Remote Areas

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A discovered infestation of live and skeleton plants of the Class ‘A’ weed pest, Iberian starthistle (*Centaurea iberica*), in Mariposa County prompted initiation of a field and laboratory project to adapt solar heating techniques for seed eradication. To facilitate off-site methods testing, seeds of invasive, but non-quarantined, tocolote (*C. melitensis*), collected from the Santa Monica Mountains Recreation Area in Ventura County, also were used. Initial field testing showed that an adaptation of the double tent solarization technique (www.solar.uckac.edu), designed for soil disinfestation, could provide inside air temperatures of more than 70° C (158 F) during warm summer days. Field and laboratory testing pointed out the critical need for moisture in the seed bags in order to obtain desired efficacy. Thermal inactivation studies were conducted on seeds exposed at 42°, 46°, 50°, 60° and 70° C. The studies showed that, at the higher temperatures of 60° and 70° C, seeds of both *Centaurea* species tested could be inactivated over the course of a single day of treatment under the Mariposa County field conditions. This technique may be of value for on-site eradication of seeds from localized infestations of invasive weed pests. It could be adaptable to on-site use for infestations discovered in remote areas, where attempted transport of seeds or seed-bearing material might result in unwanted seed dispersal.

# An Assessment of Control Methods for Cape Ivy in Coastal Riparian Ecosystems

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## Abstract

This study will measure the success and cost-effectiveness of three control methods for Cape ivy (*Delairea odorata*), a non-native invasive plant, in riparian areas in the Central Coast region of California, over the course of twelve months. Success of each control method will be determined by to the method's ability to control Cape ivy as well as its effect on the recovery of native vegetation. The objectives of this research are to inform policymakers and resource managers of the achievable outcomes and associated costs of Cape ivy control.

Specific questions that will be answered by this research include:

- What control method achieves the highest reduction of Cape ivy cover twelve months after initial treatment?
- What control method is most cost-effective (per dollar) for Cape ivy control over twelve months?
- What control method results in the highest native plant cover twelve months after initial treatment?
- What control method is the most cost-effective in promoting native plant recovery twelve months post-initial treatment?

The results from this study will also inform policymakers and resource managers of the potential need for post-disturbance treatments. Additionally, this research will contribute to urgently needed guidelines on how to restore Cape-ivy infested riparian ecosystems.

## Introduction

Cape ivy (*Delairea odorata*), native to South Africa, is an invasive plant with considerable impacts to ecosystems (Cal-IPC 2005). This deleterious invasive vine is currently expanding its range in coastal California and Oregon. The California Invasive Plant Council (Cal-IPC) lists Cape ivy on its High List as a "Species with severe ecological impacts on ecosystems, plant and animal communities, and vegetational structure" (Cal-IPC 2005). In areas containing predominantly Cape ivy, native species seedling richness has been shown to decrease 75-95% compared to pre-infestation conditions (Alvarez 1997, Alvarez and Cushman 2002). The rapid growth rate of Cape ivy coupled with the reduction of indigenous species habitat and species diversity that Cape ivy causes, make control of this species a priority (Alvarez and Cushman 2002).

While several trials and some studies have been completed to test effectiveness of control methods, there is a need for studies that compare control methods and the cost of different control methods. There is a lack of replicable, quantitative studies that compare success and the cost-effectiveness of different control methods for Cape ivy in the current scientific literature. A review of all published studies related to control and management methods for Cape ivy produced only three publications in which the results of control methods were quantified (Bossard and Benefield 1995, Bossard et al 2000, Fagg 1989). Each of these studies focused on a particular control method (herbicide treatment or flaming) rather than a comparison of control methods. Additionally, none of the identified studies provided a quantifiable comparison of the cost-effectiveness of control methods for Cape ivy. This information is needed by resource managers to make management decisions regarding Cape ivy control in riparian areas (T. Hyland, California State Parks, pers. comm. May 1, 2008; B. Delgado, Bureau of Land Management, pers. comm. March 22, 2008; G. McMenamin, Restoration Consultant, pers. comm. April 18, 2008, Robison 2006).

## Methods

Within this restoration experiment, I will measure the success and cost-effectiveness of three control methods for Cape ivy. I will quantify the effects of three control methods on Cape ivy cover and the regeneration of native vegetation. Following the application of control methods to plots at three sites, the regeneration of the plant communities (native and invasive plants) will be monitored every other month over a period of twelve months. The resiliency of the riparian ecosystem, at all three sites, to return to pre-disturbance conditions (measured by increase in native plant cover) or a trajectory close to that within twelve months, will be quantified. If resiliency is not displayed by these ecosystems, this will support the hypothesis that additional human intervention is needed to move the community from the altered state (Cape ivy dominated) to a more desired state (high native plant cover). Research activities will take place at three locations within Santa Cruz and Monterey counties beginning June 2008 and concluding August 2009.

The following control methods will be tested: 1) Modified Scorched Earth (a hand removal method), follow up with hand removal; 2) Rodeo + Activator 90, follow up with hand removal; 3) Rodeo + Activator 90, follow up with Rodeo + Activator 90. Based on recommendations, Cape ivy life history and species protection measures, I determined the best times for initial application of methods to be July-September with follow-up treatment in January-March. Rain will dictate when I will apply herbicide at the sites. The herbicide treatment will be applied with a backpack sprayer. To avoid herbicide drift that may affect nearby non-herbicide treatment plots, I used wind blocks made from PVC pipe and filter fabric at the edge of treatment plots during spray times. The modified scorched earth method used involves using only hands to remove Cape ivy, including all Cape ivy roots. After removal, Cape ivy was left on a tarp, on-site to decompose.

I have replicated each treatment ten times at each site in 2.71m x 3.41m plots, amounting to 40 treatment plots per site (120 plots total). I chose this size of treatment plot to allow for a 1m perimeter around the sampling unit, which will be a centered and nested 0.71m x 1.41m quadrat within the 2.71m x 3.41m treatment plots. This 1m perimeter is needed to avoid edge effects from adjacent areas containing non-treated Cape ivy. Because Cape ivy grows vegetatively, one Cape ivy plant can grow as much as one foot per month (Alvarez 1997, Hillis 1994).

To directly evaluate the influence of the three Cape ivy control treatments on the regeneration of the plant community, I will sample for species specific percent cover, and plant species richness every two months (or 60 days). These vegetation sampling data will allow me to evaluate the resiliency of the ecosystem at each of the study sites following application of control methods (disturbance). Cost-effectiveness of methods will be compared by increased cover of native plants per dollar spent; increased native plant species richness per dollar spent, and decreased cover of Cape ivy per dollar spent. I will use ANOVAs, MANOVAs, and mixed effects regression models in the statistical analyses of collected data. Specifically, I will examine the effects of the method of Cape ivy removal on species density and species richness of all plants and of native plants only.

### Discussion

The expected results of this study will vary, however the outcome of this investigation should answer several questions: 1) Which treatment method is the most cost-effective and successful for control of Cape ivy in riparian areas in the Central coast region of California? 2) How do different treatment methods affect native plant cover? 3) How much does it cost to successfully eradicate Cape ivy? The answers to these questions can help inform policymakers who dictate funding amounts for weed control and restoration in California. These answers will also provide valuable information to resource managers and the public about how best to control cape ivy in riparian areas in California and elsewhere. Researchers conducting research related to the control of Cape ivy, and restoration of disturbed sites may also find these results significant.

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# Goats Defeat Blackberries: Riparian Habitat Restoration Following Invasive Plant Removal at Vino Farms, Inc. Lodi, California


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## Abstract

In 2007, Vino Farms, Inc. joined with River Partners to implement a habitat restoration project on approximately 22.5 floodplain acres adjacent to their Mokelumne River vineyards. The goal of this project is to improve wildlife habitat by removing invasive plant species and planting native vegetation. This restoration project was designed to benefit a number of native riparian species including neotropical migrant songbirds, Swainson's hawk (*Buteo swainsoni*), and the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*). This project also has the potential to provide a future source for in-stream large wood critical to restoring salmon habitat in this region.

Prior to restoration, this area was dominated by invasive Himalayan blackberry (*Rubus armeniacus*), tree-of-heaven (*Ailanthus altissima)* and hybridized black walnuts. Approximately twelve acres of Himalayan blackberry were grazed by brush goats for four weeks to reduce foliage density before the canes were cleared by a mechanical masticator. Black walnuts were mechanically removed from 14.5 acres, and tree-of-heaven was cleared from one acre.

In spring 2008, River Partners planted approximately 2,500 native riparian plants including Fremont cottonwood (*Populus fremontii*) and a dense native understory with California blackberry (*Rubus ursinus*) in two floodplain fields. Native vegetation planting also occurred on the adjacent bluff and as a hedgerow along the property boundary. A dense herbaceous understory will be planted in 2009. Initial monitoring has shown over 90 % survival of planted species in the floodplain fields.


## Introduction

Prior to restoration, the floodplain fields on Vino Farms were dominated by Himalayan blackberry (*Rubus armeniacus*), tree-of-heaven (*Ailanthus altissima*), and hybridized black walnuts. This area provided little habitat for wildlife. River Partners was contracted to remove this vegetation and re-establish a native riparian community as part of Vino Farms sustainable agricultural program (Figure 1).

Restoration of a native riparian community at Vino Farms has the potential to benefit a number of resident and neotropical migratory birds by


Figure 1

Hybrid black walnut and blackberry area

providing a diversity of niches that were absent when the area was dominated by invasive plants (Inderjit, 2005). River Partners also planted blue elderberry (*Sambucus mexicana*), the host plant for the endangered valley elderberry longhorn beetle. Riparian restoration along the Mokelumne River is also a critical part of maintaining spawning salmon populations on this river (Mertz and Moyle, 2006).

### Methods

Himalayan blackberry was grazed by brush goats for four weeks before the canes were cleared by a mechanical masticator. Black walnuts were mechanically removed from 14.5 acres and tree-of-heaven was cleared from one acre. Following removal, fields were disced to remove resprouting walnuts and Himalayan blackberry. In some areas, Garlon 4 was selectively applied. The application was mixed with a mist-control and herbicide activator and applied with handheld tanks and sprayers to increase our precision and eliminate any chance of contaminating the vineyards.

After removal of the invasive species in April 2008, River Partners planted approximately 2000 trees and shrubs in four areas: two floodplain fields, along the bluff overlooking the river, and as a small hedgerow along the property boundary (Table 1). Approximately 500 live oak (*Quercus wislizenii*), valley oak (*Quercus lobata*) and snowberry (*Symphoricarpos albus*) will be planted in Fall, 2008.

### Results

Restoration plantings were censused in late July 2008. For this census, all plants were surveyed and classified as live, dead, or missing. With the exception of the bluff enhancement plantings, survivorship of planted species exceeded 85% (Table 2). Rapid growth was noted in the willows and cottonwoods. The height of cottonwoods planted in the floodplain fields averaged 179 m ± 0.34 with an average canopy width of 1.42 m ± 0.43. The average height of the arroyo willows was 1.78m ± 0.49 and the average height for the red willow was 1.47m ± 0.37.

| Plant Species | % Species Composition |
|---|---|
| Interior Live Oak (Quercus wislizenii)* | 5% |
| Valley Oak (Quercus lobata)* | 10% |
| Arroyo Willow( Salix lasiolepis) | 10% |
| Red Willow (Salix laevigata) | 6 % |
| Freemont Cottonwood (Populus fremontii) | 10% |
| Coyote brush (Baccharis pilularis) | 5% |
| Snowberry (Symphoricarpos albus) | 4% |
| Elderberry (Sambucus mexicana) | 8% |
| California rose (Rosa californica) | 14% |
| California blackberry (Rubus ursinus) | 28% |
| **Total** | 100% |

Table 1

Species composition of the Vino Farms Restoration. Oaks and snowberry will be planted in Fall, 2008.

| | | Percent Survival | | | |
|---|---|---|---|---|---|
| **Plant Species** | **Total Planted** | **Field 1** | **Field 2** | **Bluff** | **Hedgerow** |
| Interior Live Oak (Quercus wislizenii)* | Fall 2008 | Fall 2008 | Fall 2008 | Fall 2008 | Fall 2008 |
| Valley Oak (Quercus lobata)* | Fall 2008 | Fall 2008 | Fall 2008 | Fall 2008 | Fall 2008 |
| Arroyo Willow( Salix lasiolepis) | 268 | 97.2% | 87.8% | N/A | N/A |
| Red Willow (Salix laevigata) | 86 | 94.4% | 85.3% | N/A | N/A |
| Freemont Cottonwood (Populus fremontii) | 186 | 91.8% | 93.9% | N/A | N/A |
| Coyote brush (Baccharis pilularis) | 145 | 95.3% | 95.5% | 89.5% | 100% |
| Snowberry (Symphoricarpos albus) | Fall 2008 | Fall 2008 | Fall 2008 | N/A | N/A |
| Elderberry (Sambucus mexicana) | 184 | 98.2% | 97.4% | 78.8% | 100% |
| CA rose (Rosa californica) | 402 | 96.4% | 86.3% | 72.4% | 93% |
| CA blackberry (Rubus ursinus) | 650 | 94.1% | 93% | 75.5% | 90.7% |
| **Total** | **1921** | | | | |

Table 2

Plant survival on the Vino Farms restoration

Canopy widths averaged 1.20 m ± 0.59 for arroyo willow and 1.08 m ± 0.37 for red willow.

Weed control is ongoing. Fields have been disced between the planting rows to reduce and discourage resprouting. Selective treatment of Garlon 4 is used to treat larger sprouts or in areas that can not be disced.

## Discussion

Integrated Pest Management (IMP) is a strategy that utilizes biological controls, habitat manipulation and modifications to cultural practices to mange pests in an ecologically sound manner. IMP is a critical part of Vino Farm's sustainable agriculture program. The establishment of a diverse native community on this site will provide habitat niches for a number of resident and migratory birds as well as attract native pollinators. These benefits will increase the effectiveness of their IMP program.

On a larger scale, the Mokelumne River is one of the few rivers in the Central Valley with extant salmon spawning. Restoration of riparian habitat is critical for reducing sediment loading into the stream and as a source of wood critical for salmon habitat (Opperman and Merenlender 2008). Live salmon (via excretion) and salmon carcasses play an important role as a food and nutrient source for many riparian species (Cederholm *et al*. 1999).

Salmon have also been shown to have an economic benefit to riparian landowners. Nitrogen[15] is a stable isotope used to track the source of nutrients in an ecosystem. Surveys on the Mokelumne River have shown that vegetation near spawning beds, including wine grapes, derived 18-25% of their nitrogen from marine sources (i.e. salmon), reducing fertilizer costs (Mertz and Moyle, 2006). Restoration of native vegetation at Vino Farms therefore has the potential to provide ecological and economic benefits at a number of scales.

River Partners will continue monitoring and maintenance on this site for two more years. In fall 2009, a herbaceous native understory will be planted between the rows. At the end of the monitoring period, it is expected that a diverse native community will be well established at this site which should prevent future large-scale establishment of invasive plants.

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## Mapping Invasive Aquatic Plant Species in the Sacramento-San Joaquin River Delta Using Hyperspectral Imagery

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Submersed assembladges of invasive species within aquatic ecosystems pose a significant threat to ecosystem functioning and biodiversity. Effective control of invasive aquatic species requires detailed knowledge of their spatial distribution and a way to monitor changes over time. For five years, in one of the largest airborne mapping campaigns, my lab has analyzed high spatial resolution hyperspectral images measured at 3 m pixel resolution, in 126 spectral bands across the visible to shortwave infrared (0.4 to 2.5 $\mu$m) wavelength region, collected each June over 54,858 acres of waterways in the Sacramento-San Joaquin Delta. These data were used to identify locations of of the native and invasive submerged life form and emergent aquatic species using a decision tree approach to identify feature parameters from the spectrum of each target species. Map accuracy varied between 80-93% depending on year and species or life form, which was assessed using field measured GPS locations of different species and water throughout the delta. I will discuss factors related to detection of invasives in the delta and how distributions have changed with time.

## Jubatagrass Control and Natural Regeneration of *Cirsium fontinale* var. *fontinale* (Fountain Thistle)

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### Abstract

The San Francisco Public Utilities Commission (SFPUC), over a period of several years, has been conducting a project to restore the habitat of the federally endangered fountain thistle (*Cirsium fontinale* var *fontinale*), which has been invaded by jubatagrass (*Cortaderia jubata*). This rare native thistle occurs only in a few populations in serpentine seep and wetland habitat on the San Francisco Peninsula. Jubatagrass control has been achieved through mechanical removal of foliage and treatment of cut stems with glyphosate (50% Rodeo™). Approximately 5000 square feet of habitat have been cleared of jubatagrass to date. Population counts and mapping of populations were performed in 2007 to allow for monitoring of recolonization by fountain thistle. Follow-up assessments indicate successful recruitment of the thistle into cleared habitat, mainly on the periphery of the population. Restoration trials are planned to evaluate methods for supplementing natural recruitment.

### Introduction

The San Francisco Public Utilities Commission (SFPUC) Peninsula watershed, in addition to its primary purpose of supplying water, contains 23,000 acres under environmental stewardship. Within this area, there are fourteen rare or endangered plant species. These include four federally endangered species (*Cirsium fontinale* var. *fontinale*, *Eriophyllum latilobum*, *Hesperolinon congestum* and *Pentachaeta bellidiflora*) and one federally threatened species (*Lessingia arachnoidea*). The watersheds are also home to five species on the California Native Plant Society List 1B (plants rare, threatened or endangered in California or elsewhere) and to four species on List 4 (plants of limited distribution).

The restricted serpentine seep habitat of one these special-status species, the federally and state endangered fountain thistle (*C. fontinale* var. *fontinale*), is threatened by the invasion of jubatagrass (*Cortaderia jubata*). The SFPUC is undertaking a project to restore the fountain thistle habitat, following recommendations of the Recovery Plan for Serpentine Species of the San Francisco Bay area of the U.S. Fish and Wildlife Service. This involves removal of the jubatagrass and the mapping and monitoring of the population to track the progress of habitat restoration.

## Methods

### Chemical and Mechanical Control

Jubatagrass control has involved both mechanical removal of foliage and chemical control. Mechanical control was achieved by cutting through the base of clumps with chainsaws and other tools and removal of foliage from the site. Cut stems were then treated with glyphosate (50% Rodeo herbicide) after preliminary monitoring indicated that sensitive species, such as the San Francisco garter snake and California red-legged frog were not present. The cut foliage was removed from the site so that the soil between plants would be free for fountain thistle recruitment and to avoid input of additional nutrients.

The jubatagrass control efforts were initiated in 1997 and 1998 by G. Ciardi (U.S. Fish and Wildlife Service 1998a) and these were followed by progressive removal of jubatagrass in 2006, 2007 and 2008. Approximately 5000 square feet of jubatagrass have been cleared to date. Work performed in 2008 resulted in the removal of most of the remainder of the jubatagrass.

### Mapping and Monitoring

In 2007, the SFPUC initiated a project to map and census the population of fountain thistle. A transect was laid through the approximate center of the population, and transverse transects were used to locate the population perimeter. A complete count of plants was conducted, yielding a population of approximately 1100 plants in 2007. In 2008, this mapping was repeated to determine whether there was a change in the location of the population perimeter. Ongoing monitoring will track the progress of recolonization and expansion of the population into cleared areas.

## Results and Discussion

In the SFPUC Peninsula watershed jubatagrass has been successfully removed from fountain thistle habitat by both mechanical and chemical means. Good control has been achieved by treating cut stems with Rodeo herbicide. There are usually some escapes and some re-growth, but follow-up treatments eventually provide complete control. Because of a nearby seed source, jubatagrass seedlings occasionally appear, but these are easily removed.

Over the past eleven years, the fountain thistle site has been transformed from several thousand square feet of serpentine seep habitat mostly covered by jubatagrass to open perennially wet seep and riparian habitat available for fountain thistle colonization. The appearance of the site is now one of many dead jubatagrass clump bases that still have not fully decomposed after ten years, with open ground between them.

This open habitat has been extensively colonized by a variety of plants. A number of native plants have become established in the area. Early successional plants include seep monkey flower (*Mimulus guttatus*) and iris-leaved rush (*Juncus xiphioides*). The adjacent dry border supports a small population of the federally threatened Crystal Springs lessingia (*Lessingia arachnoidea*). One conspicuous missing element is tufted hairgrass (*Deschampsia cespitosa*), the most common associate of fountain thistle in its other SFPUC populations. A number of non-native plants have also colonized the bare soil vacated by jubatagrass. These include rabbit's foot grass (*Polypogon monspeliensis*), sow thistle (*Sonchus oleraceus*) and bull thistle (*Cirsium vulgare*).

The follow-up survey of the fountain thistle population in 2008 revealed a slight expansion into habitat formerly occupied by jubatagrass. Plant recruitment appears to be mainly in close proximity to parent plants, including some seedlings establishing in old jubatagrass clump bases. In 2008 fountain thistle plants were observed to be flowering after recruitment into habitat cleared of jubatagrass in 2006. There was an average net expansion of the fountain thistle of 1.7 feet (0.5 m) into cleared habitat between 2007 and 2008. The standard deviation of the 24 distance measurements was 4.7 feet (1.4 m).

However, in addition to range extension, there was also some contraction of the population perimeter in places. About of one third of the distance measurements recorded in 2008 were less than those recorded in 2007. This may be because fountain thistles are relatively short-lived biennial or perennials that typically die after flowering. Senescent plants may have been replaced by seedlings that established on the side of the parent plant away from the population boundary. Alternatively, if the plant at perimeter in 2007 was a seedling, the contraction may have been due to seedling mortality.

The results of the initial monitoring seem to indicate that fountain thistle colonization of habitat opened by jubatagrass removal is a slow incremental process. This may be due to intrinsic characteristics of fountain thistle life history and population biology.

Fountain thistle and its close conspecific relatives appear to fit the description of a typical K-selected species. These are plants growing in stable habitats that have attributes of greater relative longevity, slower maturation rate, fewer propagules with a greater investment of resources in each individual propagule and short dispersal distance.

The implications of these findings for fountain thistle restoration are that some of the same attributes of fountain thistle that make it so well adapted to maintaining populations in its specialized serpentine seep habitat make it a poor colonizer of this same habitat. Our preliminary measurements of population expansion indicate that it is only colonizing habitat on the margin of the present population. In contrast, field observations indicate that bull thistle and sow thistle are rapidly and extensively colonizing the newly opened habitat.

Because of the lack of autogamy and the obligate requirement of pollinators for seed production, conservation efforts that increased the size of the population will improve the long-term prospects for survival of fountain thistle. The U.S. Forest Service recovery plan sets a recovery target of maintaining a minimum of 2000 plants per population of *C. fontinale* var. *fontinale*. It notes that the probability of population persistence over the long-term is expected to be higher for larger populations because larger size decreases the likelihood of reduced viability or population extirpations due to random demographic or genetic events.

At the current rate of natural expansion through recruitment, it may take many years for fountain thistle to fully occupy the cleared habitat area. The farthest extent of the cleared habitat is 60 feet from the population edge. At the current measured rate of population expansion, 30 additional years may be required for it to occupy all of the potential habitat. This suggests that, as part of an adaptive management program, restoration efforts involving transplanting of seedlings or planting of plants grown offsite may be required in the future to supplement natural regeneration.

## Literature Cited

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