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Cal-IPC

"Wildland Weed Management on the Leading Edge"

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"Wildland Weed Management on the Leading Edge"

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Cal-IPC is a 501(c)3 nonprofit organization whose mission is to protect California's wildlands from invasive plants through research, restoration, and education.

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On the cover: Yellow starthistle dooms a bee at Mount Diablo State Park in Contra Costa County. Photo by Cyndy Shafer. Cal-IPC Photo Contest 2009.

Title page: Iceplant Bash – Attacking iceplant at Point Arena Lighthouse Headlands, Mendocino County. Photo by Joanne Abreu, submitted by Mario Abreu. Cal-IPC Photo Contest 2009.

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* Indicates presenting author in multi-author papers.

Weed worker Will Wright of Native Range, Inc. awaits his helicopter pick-up to be deployed to the next Cortaderia selloana infestation on The Nature Conservancy's (TNC) Santa Cruz Island Preserve. TNC and the Channel Islands National Park are conducting a joint island-wide Pampas grass eradication program. Photo by John Knapp, courtesy of TNC.

Foreword

Cal-IPC's 18th Annual Symposium took us for the first time to Visalia, the "Gateway to the Sequoias" where the agricultural lands of the San Joaquin Valley meet the forests of the southern Sierra. We chose as this year's theme "Wildland Weed Management on the Leading Edge" for several reasons—because leading edge spatial management techniques are so important, especially in less-invaded regions like the Sierra; because it encompasses Cal-IPC's goal of promoting the latest research and management techniques related to invasive plants; and finally because it also reflects the feelings many natural resource managers have of being "on the edge" in a period of reduced budgets and frozen work projects. The invited talks this year looked both to the past and the future. Richard Minnich of the University of California, Riverside gave his view on what California's grasslands may have looked like before European colonization, while other invited speakers addressed topics such as how climate change will affect the way we respond to invasive plants, new tools that could provide exciting innovations in control methods and early detection projects to stop the further spread of invasive plants. This Proceedings contains summaries of the papers and posters presented at the 2009 Symposium. Many of the projects are works in progress; some are not the type of work that is traditionally published in academic journals. The Proceedings provides a public record of these projects and we hope it is useful to weed workers looking for ideas to apply to their own situations.

Participants in the Herbicide Control Methods field course learn about equipment calibration. Photo by Heather Brady.

Keynote Speaker

California's Fading Wildflowers: Lost Legacy and Biological Invasions

Richard Minnich, University of California, Riverside, Riverside, CA

Spanish explorers in the late 18th century found springtime coastal California covered with spectacular carpets of wildflowers. Nineteenth century botanists and naturalists describe flower fields across the Central Valley and interior southern California. Invasive annual grasses and forbs from the Mediterranean basin and Middle-East have devastated this nearly forgotten botanical heritage. Defenders of the perennial bunch-grassland (nassella) model as the aboriginal vegetation baseline built their case on "scientific" evidence that began in the mid-19th century, but 19th century writings clearly show that bunch grasses were not important to the vegetation and that invasive species spread across California, far ahead of grazing. California wildflower pastures were displaced by invasive species without disturbance. The invasive species – fire feedback hypothesis in coastal California is refuted in view of Crespi's remarkable account (1769) of Native American burning in indigenous fuels, but may have merit in the interior barrens now covered with cured exotic annual grassland. The role of grazing should be viewed in geological time scales because the evolution of the California flora coincided with a diverse megafauna that exerted a cattle-like disturbance until the end of the pleistocene. Packrat middens document that wildflowers have been part of California's heritage as conspecifics since at least the last glacial maximum, perhaps long before. California's wildflower heritage has been overlooked because of a flawed hypothesis that bunch grasses were pervasive in the past, thus preventing us from observing, doubting, and searching for alternative evidence to construct alternative stories. California invasive grasses and forbs are productive and aggressive not because of intrinsic life traits, but because they are new world "goats on islands," without their old world pathogens. The restoration of California's wildflower flora will require management strategies involving the entire landscape, with a historical perspective. Potential avenues for effective management and conservation include spring burning, seasonal grazing by domesticated livestock, and use of old world pathogens as biological controls of invasive species.

Weed Management on the Leading Edge

From Foothills Grasslands to Alpine Peaks: Managing Weeds at the Leading Edge in Sequoia and Kings Canyon National Parks

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Sequoia and Kings Canyon National Parks, located in the southern Sierra Nevada, range from 1,370 feet in the foothills to 14,494 feet at the summit of Mt. Whitney. Invasive plant management strategies are as broad as the vegetation along this gradient, from containment of widespread weeds in the foothills to early detection and rapid response in the weed-free zones of the middle to upper elevations. Vectors of new introductions at this leading edge include pack stock, backpackers, fire crews, helicopters, construction and varied NPS operational activities, so prevention and education are central strategies. The parks are also beginning to consider how to adjust weed management strategies as the climate changes, such as shifting resources from control of established populations to early detection and rapid response. Can Sequoia and Kings Canyon National Parks remain free of yellow starthistle into the future? This is the test of the parks' management success at the leading edge.

Introduction

Sequoia and Kings Canyon National Parks (SEKI) encompass the full range of the west slope of the Sierra Nevada, from oak woodlands, chaparral and grasslands at 1,370 feet elevation, to montane mixed conifer forest, to subalpine foxtail pine and lodgepole pine forest, to alpine plant communities on the Sierra crest at 14,494 feet elevation. Species richness and abundance of non-native plants corresponds to this gradient, with highly invaded foothills, moderately invaded montane sites and sparsely invaded or pristine upper elevations, with few if any weeds above 8,500 feet. Broad expanses of these parks are either free of non-native plants or have very few non-natives present. With 97% of the parks' 865,257 acres managed as wilderness, much of that weed-free, we have a lot to save. As such, our weed management program is focused on managing at the leading edge to protect intact ecosystems, either from species moving into the park from California's Central Valley, such as yellow starthistle (*Centaurea solstitialis*) or from species moving into wilderness areas and higher elevations from frontcountry vectors within the park, such as cheatgrass (*Bromus tectorum*) and a suite of weedy annuals.

Strategies

Our primary strategies for protecting pristine or sparsely-invaded ecosystems from the leading edge are prevention, early detection/rapid response, eradicating small established populations,and working with partners.

Prevention

Preventing both new species introductions to the park and spread of invasive plants within the park is the central strategy for managing at the leading edge. SEKI established a policy on Best Management Practices for weed prevention in 2004, to include landscaping, construction and a wide range of park operations. The park avoids importing earth materials whenever possible. When import is necessary, quarries are inspected for invasive plants and are either rejected if too weedy or mitigating measures are implemented, such as requiring freshly-produced material. Construction equipment is required to be thoroughly cleaned and inspected before entering the park. The extent and frequency of soil disturbance is minimized. A Resource Advisor is assigned to all fires to evaluate risk and recommend prevention measures. Pack stock used to supply NPS trail crews are fed California certified weed-free feed. Park staff is educated and encouraged to clean their boots, clothing and equipment before moving from place to place within the park. Boot-brushing stations have been developed for major trailheads. Frontcountry sites with high potential to move propagules into pristine wilderness, such as heliports, pack stations and trailheads, are treated for invasive plants.

Projects have been designed with resistance to yellow star thistle invasion as an objective. For example, in 1990 SEKI began implementing a series of projects to rehabilitate the main park highway, starting in the foothills and moving to montane elevations. Because the surrounding grasslands were already dominated by annual Mediterranean grasses, the least noxious of these, Bromus hordeaceous, was purchased from commercial sources and used to seed road shoulders after construction. However, this practice was discontinued as the project moved upward in elevation and native perennial bunch grasses comprised a larger proportion of the surrounding grasslands and as invasive plant prevention was considered from a revegetation perspective. While annual grasses provide quick above-ground cover, they do not compete below-ground with late-developing noxious species like yellow starthistle. We were also seeing patchy, high densities of non-native legumes on the roadsides.

We have now developed a seed mix of four native perennial grasses and two native annual legumes produced from site-collected seed, with the objective of providing more effective competition for potential introductions of yellow starthistle and non-native legumes.

Early Detection and Rapid Response (EDRR)

SEKI conducts early detection surveys both to detect new introductions to the park and to detect and quickly eradicate new populations of species already present in the park, particularly after disturbances, such as fire.

Much of our early detection effort is specifically targeted to yellow starthistle not yet established in SEKI. Introductions of single plants to a dozen plants have been detected several times since 1998 and eradicated prior to reproduction. Park staff surveys roadsides in close proximity to the park boundary, as well as high-use turnouts and river access trails. The foothills area where pack stock is pastured for the winter is also surveyed. In order to increase the number of eyes looking for yellow starthistle and raise awareness of the issue, we give informational talks to park staff during annual orientations, teach them to identify yellow starthistle using customized identification cards and offer home-baked cookie rewards for new detections.

Construction sites are surveyed for invasive plants for one to three years after construction is complete and small populations are removed before they reproduce. We've had excellent success in reducing common roadside weeds by treating them thoroughly in the first year after construction, combined with seeding of native perennial grasses and legumes. Large construction projects are required to supply the funding for these surveys.

The resource-rich environment following fire, both prescribed fire and wildfire, is ideal habitat for several montane-zone invasive plants, particularly bull thistle (*Cirsium vulgare*) and EDRR is critical for practical management of these populations. Unfortunately, the NPS fire program only provides funding for EDRR following suppression fires; no funding is available for either management-ignited prescribed fires or lightning-ignited prescribed natural fires. EDRR in recent burns is therefore conducted when staff or volunteers are available.

The early detection efforts described here are ad hoc, conducted in the areas we think are most critical with the staff that is available. In the next five years we plan to develop a comprehensive early detection strategy and plan, with which we hope to attract funding. At 865,257 acres, these parks are too large to completely survey and census for invasive plants. To narrow the search window, we plan to prioritize sites for early detection based on their resource values and their probability of being invaded. In addition, we plan to incorporate sites that may be more vulnerable to increased rates of invasion because of climate change. We will then develop a strategy for surveying these areas on a planned rotation, with some areas surveyed annually and others less frequently.

While we are interested in detecting and eradicating any non-native species introduction into pristine sites, we have also prioritized species for early detection based on their impact, threat and current limited distribution. A watchlist of species not yet detected in the park, but present in surrounding areas, has also been developed.

These prioritized species lists will support the creation of detection tools, such as species identification cards, to support early detection efforts by staff that may not have the botanic skills to recognize a plant that doesn't belong. Climate change considerations will also be incorporated into these watchlists. In 2007-08, Cal-IPC began incorporating climatic modeling into its weed risk mapping effort. These maps can tell us which species are increasingly likely to find suitable habitat in the southern Sierra Nevada as a result of climate change. For example, under current climate conditions, habitat suitability for French broom (*Genista monspessulana*) in our area is "Very Low". Under a climate-change scenario (+3° C), habitat suitability for French broom is predicted to be "High." This would elevate French broom's position on the park watchlist.

Eradicate Small Populations

We have successfully eradicated very small populations of highly threatening plants, such as yellow starthistle (*Centaurea solstitialis*), giant reed (*Arundo donax*), French broom (*Genista monspessulana*) and Spanish broom (*Spartium junceum*). Focusing our control efforts on these very small, highly threatening populations prevents the leading edge from spreading further into the parks and becoming much more difficult and costly to control.

A challenge facing the park right now is effective control of very limited-distribution, still small, but very difficult to control populations of perennial grasses in montane meadows, primarily reed canarygrass (*Phalaris arundinacea*) and velvet grass (*Holcus lanatus*). Reed canarygrass, which is native to parts of California but non-native to the southern Sierra Nevada and has also hybridized widely with European and cultivated strains (Gerlach et al. 2003), is located only in the Grant Grove area of the park. It is a high priority for management because of its limited distribution and high impacts, but control of this rhizomatous, thatch-forming species is very difficult and requires a five to ten-year commitment. Funding is generally available only for three years of initial control, making follow-up very difficult. However, the threat of these populations spreading more widely into the wilderness is high; in 2009 a small reed canarygrass patch was detected in a wilderness meadow. In this case, controlling the established population of reed canarygrass in Grant Grove is a strategy for preventing its spread to other parts of the park.

Partnerships

A final critical strategy for managing at the leading edge is working with partners to keep buffer areas free of invasive plants. Yellow starthistle and giant reed arrived in the park's main gateway community, Three Rivers, in the last decade or so. Working with the Tulare County weed management area, the Three Rivers community, particularly local realtors, has become active in promoting a yellow starthistle control program on private land. The WMA and Natural Resource Conservation Service surveyed and controlled giant reed in the Kaweah River while it was still manageable. We have had very high participation from landowners, but the challenge is always to get every landowner to participate. Direct outreach to these landowners is a critical need.

Future Management Priorities

Climate change in the Sierra Nevada is expected to greatly exacerbate invasive plant problems, through range expansions from lower to higher elevations, through these species' abilities to exploit niches no longer suitable for native species and through the interaction of climate and fire, creating more and novel types of disturbances. Invasive plant management strategies will need to adapt to these rapid movements of invasive plants. There are vast areas of these parks that currently sustain very low levels of invasions. To have any hope of being effective in maintaining these nearly weed-free ecosystems, early detection and rapid response will need to be the central strategy.

The park is currently considering shifting resources from control of established populations toward EDRR and has proposed using a decision-support system to evaluate this (Martin et al. 2007). Although we state that prevention and EDRR are the highest priorities of the weed management program in SEKI, in practice they do not get the resources necessary to do them comprehensively and consistently. Because funding is generally available only for control of established populations, our long-term resources and institutional knowledge is put toward supporting large control projects and prevention and EDRR suffer.

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Managing the Leading Edge: Landscape-Level Control of Invasive Plant Spread in the Sierra and Beyond

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Abstract

Invasive plant populations at a range of scales often have "leading edges" where the population is expanding spatially into previously uninfested territory. These leading edges present potential management opportunities for preventing the further spread of a population. An effective leading edge program requires solid distribution data for the species, preferably over a time period long enough to document the rate, direction and mode of spread. This spatial data provides the basis for defining a leading edge containment line and for setting program goals. The second essential component is a management program that can eradicate infestations that occur outside the containment line. By comparing programs designed around the leading edge concept, we will determine common features, best practices and specific challenges. As California's natural resource managers increase regional capacity for early detection networks, it will be key to consider leading edge principles for designing effective management response.

Introduction

Strategies for managing invasive plant populations, no matter what the scale, are often spatial in nature. Managers decide to focus efforts on particular areas that are most critical. The "leading edge" concept is a simple but important concept in shaping spatial strategy. The basic steps to establish a leading edge containment zone include: 1.) map the main population in order to establish a "no-spread line"; 2.) monitor and survey along the no-spread line, including areas most likely to support spread (e.g. disturbed areas) and areas with high conservation value; 3.) eradicate outlier populations beyond the no-spread line and 4.) continue annual surveys and treatment to prevent spread beyond the no-spread line. Through evaluation of invasive species leading edge and barrier projects conducted throughout the United States, we identify common elements leading to successful containment and how these management strategies may be incorporated into projects here in California.

Methods

Invasive species case studies from around the United States were reviewed to identify common elements that might be useful to California land managers in designing leading edge programs.

Melaleuca Management in South Florida

Melaleuca quinquenervia (Cav.) Blake is native to Australia and was introduced into Florida in the early 1900's as an ornamental tree and commercial source of wood. By 1987, the tree had invaded 7.7 million acres in ten counties south of Lake Okeechobee with 46,793 acres of monoculture. In 1990 the Florida Exotic Pest Plant Council and the South Florida Water Management District convened a task force to recommend a strategy to manage Melaleuca by first defining the "leading edge" at the south rim of Lake Okeechobee. The second strategic element included treating single trees (especially those most distant from primary stands) to begin creating Melaleuca-free buffer zones. More than 78 million stems (mature trees and saplings) have been treated and/or removed since control efforts began. The Melaleuca project (including biological, mechanical, chemical and physical control efforts) has cost about $25 million thus far. To place this in perspective however, the Florida Department of Environmental Protection estimated that failing to act against Melaleuca would ultimately cost the region $161 million annually in lost revenues and other impacts.

Continental Divide Barrier Zone

Rush skeletonweed (*Chondrilla juncea*) occupies millions of acres in Idaho and is spreading predominately north- and east- ward through the high country into Montana. The bi-state project partners have worked to anticipate the invasion path by first completing accurate landscape-scale mapping of existing populations including digital aerial sketch mapping and ground surveys. Passive monitoring by user groups have also supplemented formal detection surveys. In addition, susceptibility models that incorporate solar angle, wind, cover, etc. have been analyzed to assist in defining the path and developing a barrier zone. (Goodwin et al. 2009). This Continental Divide Barrier Zone now comprises over 13 million acres along the borders. A key strategy highlighted in this project is to ensure that local and county financial needs are met for early detection and treatment to protect additional lands and assets at the larger, regional scale.

100th Meridian Initiative

The 100th Meridian Initiative is a cooperative effort to prevent the westward spread of zebra mussels and other aquatic nuisance species in North America. This project is a classic example of drawing a line in the sand. In this case, the 100th meridian line has been used historically to define "The West", so the campaign is able to leverage western pride and regional protectiveness through this name. With increasing recreational boating and boaters traveling long distances between water bodies, the potential is there for long distance dispersal. In this case, guarding the leading edge means addressing a human pathway for spread with boat inspections and public outreach and education.

Managing Sudden Oak Death in Southwest Oregon Forests

Sudden Oak Death (SOD), caused by the pathogen *Phytophthora ramorum*, was first discovered in Oregon forests in July 2001. Since then an interagency team has been working with landowners to contain and eradicate the pathogen. A quarantine zone has been established encompassing all of Curry County in southwest Oregon as a means to protect Oregon's natural resources from the artificial (i.e. human) spread of Sudden Oak Death. The success of "leading edge" management of SOD in Oregon depends upon thorough, regular early detection and rapid response measures including low-flying aerial and ground surveys. A site containing even a single confirmed or probable SOD infection is scheduled for immediate mandatory treatment of the infected trees, plus host reduction. The Oregon Department of Forestry (ODF) is now working to establish an aggressive 'host reduction zone' – essentially a "leading edge" zone. To date, the ODF has had modest success at eradication, but very good success at limiting spread and containing the pathogen to a relatively small area.

Slowing the Spread of Gypsy Moth

Gypsy moth (*Lymantria dispar*) is a destructive, exotic forest pest that was accidentally introduced into the United States in 1869. It is currently established throughout the northeast and upper mid-west, feeding on over 300 species of trees. A Slow the Spread strategy was integrated into the national program for managing the gypsy moth in 1999. The current proactive strategy, funded by Congress in 2000, has implemented a region-wide strategy to minimize the rate at which gypsy moth spreads into uninfested areas. As a direct result of this program, spread has been dramatically reduced by more than 70% – from the historical level of 13 miles per year to three miles per year (Sharov et al. 2002). In just eight years, this program has prevented the impacts that would have occurred on more than 75 million newly infested acres, yielding a benefit to cost ratio of almost three to one. These benefits have been achieved with a partnership investment of state and federal funds ranging from $11 million to $13 million annually. The Slow the Spread Foundation manages the project and oversees the budget, allowing federal resources to be shifted from one state to another depending on priorities and biological need.

Stop the Spread of Yellow Starthistle into the Sierra Nevada Mountain Range

A coordinated, regional project to control Yellow starthistle (*Centaurea solstitialis*) (YST) populations at an eastern leading edge line across thirteen Sierra foothill counties was initiated by California Department of Food and Agriculture in 2007. Project elements include: 1.) baseline surveying, mapping and control of YST to establish an eastern leading edge line, 2.) detection and eradication of outlier YST populations beyond the "no-spread" line, 3.) establishment of a centralized mapping database to document results, 4.) annual monitoring surveys and treatment to maintain the line and eradicate outliers and 5.) outreach and education to landowners and land managers on preventing the spread of YST. Utilizing the Weed Management Area (WMA) infrastructure and a project coordinator, increased coordination between landowners and agency land managers will allow resources to be utilized more effectively to protect the valuable assets of the Sierra Nevada region.

Results and Discussion

These examples illustrate the concepts and benefits of using a leading edge approach to program design for invasive species control. By comparing programs designed around the leading edge concept, we have identified common features, best practices, and specific challenges, including:

- Detection surveys, mapping and long-term monitoring are essential – knowing the baseline and prioritizing treatment strategies are the foundation of a successful leading edge project.
- Coordination, usually in the form of a paid coordinator or other formalized structure, is important to identify and engage all stakeholders and land managers in developing and implementing a strategy.
- Funding sustainability and flexibility (e.g. a foundation that can easily shift resources depending on priority and biological need) is important to the effectiveness of a leading edge project.
- Prevention outreach and educational campaigns are valuable project components, since the introduction of outlier populations is often due to human activities.

It is important to routinely re-examine assumptions that may be built into our spatial strategies. For instance, in the Sierra we used to make certain assumptions about elevational barriers to invasive plant spread. In recent years, detection surveys have shown that invasive plants are spreading into remote areas previously thought to be safe from invasion. This is partly due to increased site disturbance (e.g., construction, road development) and the associated movement of materials and equipment at the wildland-urban interface as communities in the region grow. It is also due to our imperfect understanding of the environmental limitations for each species and the fact that these limitations may change as an introduced species continues to adjust to new conditions. Additional spread in foothill and mountain areas is also anticipated due to climate change, with range expansions from lower elevations. As California's natural resource managers increase regional capacity for early detection networks, it will be key to consider leading edge principles for designing effective management response.

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The Role of Animals and Disturbance in Plant Invasion: Lessons from the Carrizo Plain

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Abstract

Annual grasses and forbs that originated in the Mediterranean-region quickly came to dominate California's grasslands soon after European settlement. Incredibly, these massive invasions and the processes that facilitated them went completely unnoticed at that time. A synthesis of historical information and modern ecological studies of grasslands at Carrizo Plain National Monument and elsewhere indicates that native small burrowing mammals (e.g., ground squirrels, gophers and kangaroo rats) were key facilitators of these early invasions. A large body of evidence indicates that, historically, populations of these rodents were huge and that their soil disturbances were chronic and extensive. Enormous expanses of grassland were riddled with patches of disturbed soil. When the ruderal and opportunistic plant invaders encountered these disturbed microenvironments in California, they were conveniently pre-adapted. Therefore, the widespread rodent-produced disturbed soil patches served as nascent foci for invasive species, enabling them to disperse rapidly across broad grassland landscapes by hopscotching from patch to patch. It is likely that seed dispersal by animals also played an important role in this invasion process. These relationships extend into modern times because burrowing rodents continue to be very abundant in grasslands. Disturbance and dispersal by small native animals are among the factors that enable invasive annuals to persistently dominate California's grasslands and they complicate the task of resource management in these now rare ecosystems. It is likely that facilitation relationships between non-native plants and native animals exist elsewhere in California as well and that their relevance to conservation and restoration are underappreciated.

Introduction

Considerable evidence exists indicating that, prior to the invasion by grasses and forbs from the Mediterranean region, California's prairies ("grasslands") were dominated by a diverse array of native annual forb species (for relevant literature citations, see Schiffman 2000, 2005, 2007a). Forbs were particularly important native constituents in arid areas, including the Carrizo Plain and the southern San Joaquin Valley. Hundreds of native forbs continue to persist to the present day; however, they no longer dominate the remaining wild vegetation. Instead a few invasive non-natives (for example, *Erodium cicutarium, Bromus* spp., *Avena* spp., and *Hordeum murinum*) cover most of the ground each spring and the native annual forbs have been relegated to the sidelines – appearing as either as scattered wildflowers or, infrequently, as ephemeral carpets of color. The invasion of California's prairies and the widespread displacement of native annuals by non-native ones occurred soon after European settlement and, incredibly, went completely unnoticed by people at the time. Did these invasions happen, as conventional wisdom has suggested, because non-native plants were able to quickly exploit opportunities created when enormous herds of grazing livestock and periodic drought overwhelmed communities of native annual forbs? Or, is there more to the invasion story?

An Additional Explanation

Historical information along with modern ecological studies at Carrizo Plain National Monument and elsewhere point to native burrowing mammals (for example, ground squirrels, pocket gophers, kangaroo rats) as key facilitators of the invasions (Schiffman 2000, 2007b). An impressively large body of historical evidence (particularly diaries written by some of California's earliest European and American settlers, explorers and naturalists) indicates that, historically, populations of burrowing rodents were enormous and that patches of their soil disturbances riddled entire prairie landscapes. For example, when traveling through the San Joaquin Valley in 1776, Pedro Font wrote in his diary that "we came to some bare hills which, because they were mined by ground squirrels we named the Lomas de las Tuzas" (Bolton 1966, p. 410). In that same year and also in the San Joaquin Valley, Francisco Garcés described the environment that he encountered as a "level plain much undermined by tusas of which there are infinite numbers...; we fell down, the mule and myself and several times I was in danger of the same, because of the insecurity of the ground." (Coues 1900, p. 301).

These extensive patches of animal-disturbed soils likely served as "nascent foci" (Moody and Mack 1988) for the opportunistic and disturbance-adapted invasive plants, enabling them to disperse rapidly across many thousands of hectares of California's prairie by hopscotching from patch to patch to patch. In addition, the process of invasion would have involved dispersal of non-native seeds by native mammals. Granivores, such as kangaroo rats, are well known to be prodigious collectors and transporters of seeds, including non-native grasses. However, herbivores, including rabbits, hares and pocket gophers, also disperse many viable non-native seeds and, therefore, are also almost certainly responsible for aiding their spread (Schiffman 2007b). The tremendous abundance of these animals and their propensity to chronically disturb the soil and as well as disperse seeds meant that California prairies were extremely vulnerable to invasion and that the it was possible for a large region to become thoroughly invaded in a matter of just a few years.

Conclusion

These ecological interactions, essentially facultative mutualisms, between non-native plants and native mammals continue into modern times and are among the reasons that the invaders are able to persistently dominate California's prairies. They also complicate the task of management in these rare ecosystems. It is likely that similar facilitation relationships between invasive plants and native animals also exist in other California environments. Is it possible that, in our efforts to prevent invasions and eradicate invaders, plant ecologists, restorationists and habitat managers are too narrowly focused on the plants? Are the animal species, with which the invasive plants co-exist and interact, receiving adequate attention? Lessons learned in the prairie of Carrizo Plain National Monument suggest that understanding plant-animal interactions is necessary if we are to address the challenges posed by invasive plants.

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Poster Session

Student Poster Session

Evidence that Plant-Associated Methylotrophic Bacteria Aid in Grassland and Coastal Sage Scrub Restoration

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Abstract

Recent evidence suggests that plant-microbe interactions can play a role in the success of biological invasions and therefore may affect restoration outcomes. Pink-Pigmented Facultative Methylotrophic bacteria (PPFMs, Methylobacterium) are mutualists associated with the roots, leaves and seeds of terrestrial plants. Previous studies have shown that PPFMs enhance plant germination, growth rates and productivity and even confer drought and pathogen resistance. Here we investigated the distribution of PPFM abundance along gradients of invasion in a California coastal sage scrub ecosystem. We found that the abundance of PPFMs varied between plant species and that the zones of mixed native/non-native species in invasion gradients harbor fewer PPFMs compared to pure zones. Further, we found that the herbicide, glyphosate, reduces PPFM abundance. An in vitro experiment manipulating glyphosate and PPFMs showed that glyphosate-treated non-native mustard (*Hershfeldia incana*) seeds germinated earlier than controls, possibly due to the loss of PPFMs. In contrast, native seedlings (*Artemisia californica*) benefited from the presence of PPFMs by reducing germination time and increasing seedling size. In a Southern California grassland restoration that had been treated multiple times with glyphosate, we found an order of magnitude fewer PPFMs in glyphosate-treated soil compared to control soil. Spraying a 20% methanol solution, a PPFM substrate, on the post-glyphosate treated soil resulted in a 30% increase in *Nassella pulchra* germination rates and seedling size. Together, these results suggest that increasing PPFM populations may be a promising method for understanding plant-microbe interactions in invasions and improving restoration outcomes.

Introduction

Recent work combining theories of community ecology with plant-soil interactions has helped improve restoration success. Most of the studies that link invasions with plant and soil microbe interactions have focused on the nitrogen-fixers and mycorrhizal fungi. Few of the feedbacks that have been found are strong enough to explain the spread of invasive plants (Levine et al. 2006) or to generally improve restoration outcomes. Are we overlooking other mutualists that may strongly contribute to restoration success?

Pink-Pigmented Facultative Methylotrophic bacteria (PPFM, Methylobacterium) are phytosymbionts that could be as important in natural systems as they are in agricultural systems. PPFMs are well studied in agricultural systems due to their importance in seed germination, growth, crop yield, pathogen resistance and drought stress tolerance (Trotsenko et al. 2001) but are not as well studied in natural systems. PPFMs utilize C1 compounds generated by growing plants, such as methanol. Studies have shown that crop species have different abundances of PPFMs in their phyllosphere, suggesting that there may be an optimal number of PPFMs for plants. Plants that harbor PPFMs are thought to have competitive advantages that could be important factors in restoration success, particularly in Mediterranean climates.

Further, since restorations often include the use of herbicides, it is important to understand how glyphosate, a commonly used herbicide, affects not only plants but also their microbial mutualists (Harris 2009). No previous work has tested the PPFM response to glyphosate. To begin to understand how PPFMs interact with plants in natural communities we surveyed PPFM abundance in the rhizosphere of native and exotic plant species in coastal sage scrub (CSS) habitat. With this information we asked:

1. Does PPFM abundance vary by native or exotic plant species or in pure or mixed stands?
2. Are there fitness consequences to native plant germination with PPFMs?
3. Since glyphosate is often used in restorations, are PPFMs and seedling fitness or survival affected? If so, is methanol application a feasible remediation tool after glyphosate use?

We hypothesized that PPFM abundance would differ between species and that PPFMs would benefit natives relatively more than exotics. Further, that glyphosate would inhibit PPFMs and natives would suffer negative effects as a result.

Methods

PPFM abundance in invasion gradients was surveyed using rhizosphere soil from five CSS and five invasive species at one park in the Santa Monica Mountains National Recreation Area (SMMNRA). We identified ten invasions that had an area of pure CSS, a 50/50 mixed zone and 100% invaded zone. We performed serial dilutions of the soil from three samples/species in each zone of the gradient to determine the most probable number (MPN) of bacteria/g dry soil (N=162).

PPFM sensitivity to glyphosate was tested using a PPFM culture that was spread onto selective agar media for PPFMs. Sterile filter paper disks infused with glyphosate (1%, 2%, 4%, 10% and 41%) were placed on the agar (N=5 each treatment) and incubated at 30°C. The diameter of the zone of clearing around each disk was measured. A larger zone of clearing indicated greater sensitivity to the glyphosate concentration.

A laboratory seed germination experiment tested the fitness consequences of glyphosate and PPFMs on a native CSS shrub, *Artemisia californica*, and the exotic mustard, *Hershfeldia incana*. Treatments (2% glyphosate, PPFMs, and glyphosate x PPFMs) were sprayed onto seeds kept moist on filter paper in Petri plates (25 seeds/plate, N=250/treatment/species) and incubated at 20° C. Sterile water was added to the controls. Seed germination was recorded daily. Seedling length and the number of seeds with mold infections were recorded after 14 days.

The efficacy of a 20% methanol addition to improve native seedling fitness, germination rates or seedling size was tested in a grassland restoration (25 acres, SMMNRA) after multiple glyphosate (2% RoundUp) treatments cleared all vegetation. Methanol provides a substrate for the remaining PPFMs in the soil. Before the site was drill seeded with *Nassella pulchra*, the abundance (MPN) of PPFMs was tested in five soil samples collected in glyphosate treated and control areas as before. Three days after drill seeding, five blocks (two one-m^2 plots/block/treatment, separated by 0.40 m) were established. Each plot received a 20% methanol application or an equivalent amount of water as a control. One month later, the plots received an additional treatment (20% methanol or water). In early May and July 2009, we counted the number of N. pulchra seedlings and recorded their basal width (mm).

Results

Different plant species have a different abundance of PPFMs in their rhizospheres (P=0.0002) but there does not appear to be a separate pattern for natives versus exotics. However, there tend to be fewer PPFMs where natives and exotics are mixed 50/50 in an invasion gradient (marginally significant, P=0.08). From the culture and sensitivity assay with glyphosate, we found that PPFMs are sensitive to every concentration of glyphosate we tested (1%-41%). As the glyphosate concentration increased, so did the zone of clearing (P<0.0001). We found an order of magnitude fewer PPFMs in soil receiving multiple 2% glyphosate treatments compared to controls (3700 cells/g dry soil vs. 32000 cells/g dry soil in control areas, P<0.007). From the in vitro seed germination study manipulating PPFMs and glyphosate, we found that PPFM inoculation had various beneficial effects on native seedlings while glyphosate had negative effects. Native seeds first germinated on average at Day Five when inoculated with PPFMs, on Day Six in the controls and on Day Seven in the glyphosate treatments. PPFMs increased native seedling size compared to control or glyphosate treatments (P<0.0001, Figure 1). However, the exotic seeds showed the opposite pattern, germinating a day earlier in the glyphosate treatments than control or PPFM treatments. There were no differences in the number of *H. incana* seeds germinated (98% by day 6) or seedling length by treatment. Glyphosate protected seeds of both species from mold infection (P<0.0001), indicating that glyphosate is killing some fungi as well as PPFMs. The 20% methanol solution in the field significantly increased the number of N. pulchra that germinated (24%, P=0.04, Figure 2) and their size (30%, P<0.001). The positive effect on size persisted over three months (P<0.008, Figure 3).

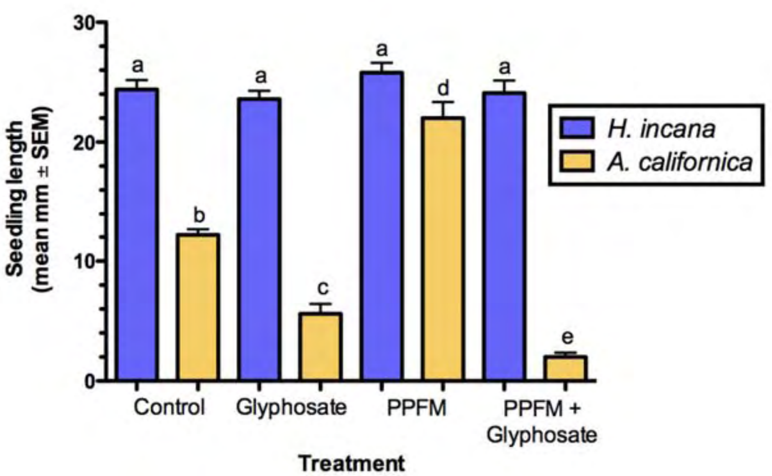

Figure 1

In vitro seedling length - root to cotyledon tips. (2-Way ANOVA on A. californica: F=111.6, P<0.0001*, DF=3, N=39; 2-way ANOVA on H. incana F=1.25, P=0.3, DF=3, N=40. Tukey pairwise tests: A. californica P<0.0001), H. incana NS)

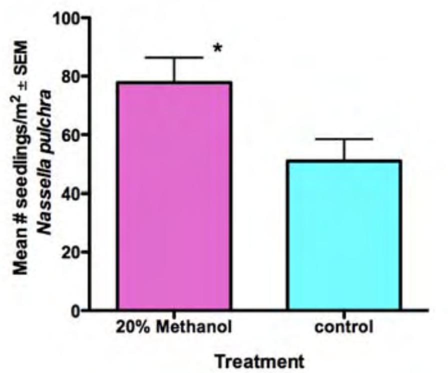

Figure 2

Average number of N. pulchra seedlings germinated at SMMNRA restoration site after glyphosate treatment. (1-Way ANOVA: mean control 51 ± 7.48 SEM, mean 20% methanol 78 ± 8.62 SEM, F=5.519, P=0.04*, DF=1, N=5; No block effect)

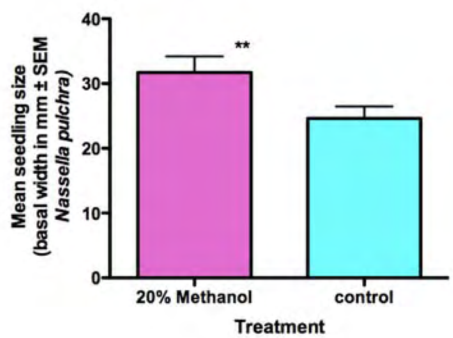

Figure 3

Average seedling size (N. pulchra) at 3 months post-methanol treatment.

(1-way ANOVA, F=7.45, P=0.008*, DF=1, N=43 control & N=30 methanol treated; No block effect)

Discussion

Taken together, our results suggest that PPFM abundance can be manipulated to improve the outcome of restorations in CSS and grasslands. Further work is needed to survey many plants in differing community types to see if these results can be generalized to other species and ecosystems. We plan to test the effects of methanol and PPFM addition on the germination and early establishment of multiple natives and exotics, after glyphosate use, in a field experiment. The effects of other herbicides on PPFMs should also be tested. The 20% methanol application we tested is an inexpensive, effective remediation tool now available to land managers after glyphosate has been used. By inoculating native seeds or seedlings bound for restoration sites with PPFMs, we may further improve the natives' ability to compete with exotics, especially early on. Our finding that mixed zones in an invasion gradient harbor fewer PPFMs is intriguing because PPFMs may be responding to increasing organics, perhaps allelopathic, exuded by roots during competition (Reinhart & Callaway 2006). Further work into the mechanisms allowing plants and PPFMs to interact may offer new insights into invasion dynamics and belowground plant competition.

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Genetic Identity and Phylogenetic Relationships of Invasive Brooms in California

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Abstract

More than half of the most highly invasive plants in natural areas of California arose from the horticultural trade. These invaders are often difficult to identify as a result of hybridization among ornamental cultivars and species and naturalized populations. Evidence of hybridization is important because hybridization can increase invasiveness and make management, especially biological control, difficult. The goal of this research is to identify the cultivated sources of invasive broom populations in California, and determine whether hybridization between ornamental cultivars, species and populations in natural areas has occurred. To determine the species identity and evolutionary history of invasive broom populations in California, we are assessing genetic variation in ornamental and invasive plants at nuclear and chloroplast DNA regions. We are reconstructing a phylogeny of the brooms as a whole and of a densely sampled French broom group, to determine the identity and origins of invasive brooms in California. Preliminary results suggest multiple origins of invasive French broom in California. Chloroplast and nuclear DNA sequence data reveal a clade of invasive French broom closely related to both *Genista monspessulana* and *Genista canariensis* from the native range. Urban broom invasions are more closely related to ornamental sweet broom than to other invasive French broom. In addition, one invasive individual is likely a hybrid between Scotch broom and French broom. Our results have implications for understanding the genetic and demographic processes that underlie the success of invasive plants of horticultural origin and for working with the horticultural industry to prevent the introduction of potential invaders.

Introduction

Human activities, such as immigration and international trade, promote exotic plant invasions by dispersing species outside of their native ranges. The horticultural industry provides a constant supply of nonnative plants and 82% of the woody invasive plants in the United States were introduced for horticultural use (Reichard, 1997). A variety of potentially invasive plants continue to be sold commercially and a combination of taxonomic and genetic research on horticultural plant invasions is necessary to determine the cultivated sources of invasive populations.

Ornamental plantings can contribute to invasive populations through both genetic and demographic processes. Adaptation to a novel environment typically requires genetic diversity. The presence of different cultivars and closely related species can increase the genetic diversity in an invasive population via intra- and inter- specific hybridization or multiple introductions (Ellstrand and Schierenbeck, 2009). Alternatively, repeated introductions of seeds from cultivated plantings can promote invasive populations by providing a constant supply of propagules and rescuing naturalized populations (Lockwood et al, 2005).

Utilizing brooms in California as a model system, we are using molecular phylogenetic tools to distinguish between the genetic and demographic processes contributing to an invasion. French broom is a woody exotic legume that was introduced into California in the mid-1800s for landscape planting. Although invasive French broom in California is typically assumed to be *Genista monspessulana*, this has never been tested. Alternative hypotheses include that invasive French broom is actually *G. stenopetala*, a closely related weedy species, or a hybrid between *G. stenopetala* and *G. canariensis* (McClintock, 1993). Sweet broom is a putative close relative of French broom that is currently available in nurseries under a variety of scientific names. Morphologically, it looks very similar to French broom and it is possible that ornamental sweet broom is also invasive or that it is hybridizing in the wild with French broom. The overall objective of this project is to ascertain how ornamental sweet broom contributes to invasive French broom populations to infer the relative importance of genetic and demographic effects in an invasion of horticultural origin. Our specific objectives are: 1.) determine the taxonomic status of invasive and ornamental brooms in California and 2.) assess hybridization between species and the presence of sweet broom plants in invasive populations.

Methods

46 broom individuals were analyzed. Our sampling included 23 invasive individuals from throughout California, six landscape plantings, six plants from the horticultural industry, nine Genista individuals from botanical gardens and arboreta worldwide and two samples from GenBank. DNA was extracted from silica-dried leaf material using the CTAB procedure. The nuclear ETS region and chloroplast tRNA-leu regions were PCR-amplified and sequenced using the primers and conditions described in Cubas et al (2006) and Taberlet et al (1991).

Sequences were aligned using ClustalX and phylogenetic analyses were performed separately in PAUP* 4.0 with gaps coded as missing. Maximum Parsimony (MP) analyses used heuristic searches and TBR branch swapping.

Results and Discussion

Results of phylogenetic analyses of the ETS and tRNA-leu regions in the French broom group are presented in Figures 1 and 2, respectively. Both phylogenetic trees contain one strongly supported clade (a group consisting of a single common ancestor and all of its descendents) of French broom that also contains *G. monspessulana* and *G. canariensis*. It is likely that the majority of invasive French broom in California is either *G. monspessulana*, *G. canariensis* or the result of a hybridization between these species. In both the nuclear and chloroplast trees, a small number of French broom samples do not fall within the main French broom clade, suggesting multiple origins of invasive French broom populations in California.

Three urban French broom individuals are more closely related to sweet broom, *G. stenopetala* and *G. maderensis* than they are to the main French broom clade (Figure 1). One invasive individual from Southern California is most closely related to a landscape planting of sweet broom, which suggests that ornamental sweet broom contributes directly or via hybridization to invasive broom populations. While sweet broom all falls into one clade, some individuals appear to be *G. stenopetala* and at least one individual may be *G. maderensis* (Figure 1).

One invasive individual identified as Scotch broom (labeled as Scotch broom: ASRA Robie Pt trail) was included in these analyses because it was found next to a stand of French broom and had unusual seed pods and foliage density. This individual had a nuclear sequence most closely related to French broom (Figure 1) and a chloroplast sequence that clustered with Scotch broom (Figure 2). This lack of congruence is most likely due to a hybridization event between Scotch broom (maternal parent) and French broom (paternal parent).

To test for hybridization between ornamental sweet broom and invasive French broom, we are presently genotyping individuals at six chloroplast and six nuclear microsatellite loci and will perform Bayesian assignment analyses to identify specific ornamental cultivars and species that are contributing to invasive populations. These results will have the potential to inform the horticultural industry and gardening public about the invasiveness, or lack of invasiveness, of ornamental sweet broom.

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Figure 1

50% majority rule maximum parsimony consensus tree of the monspessulana clade based on nuclear ETS sequences.

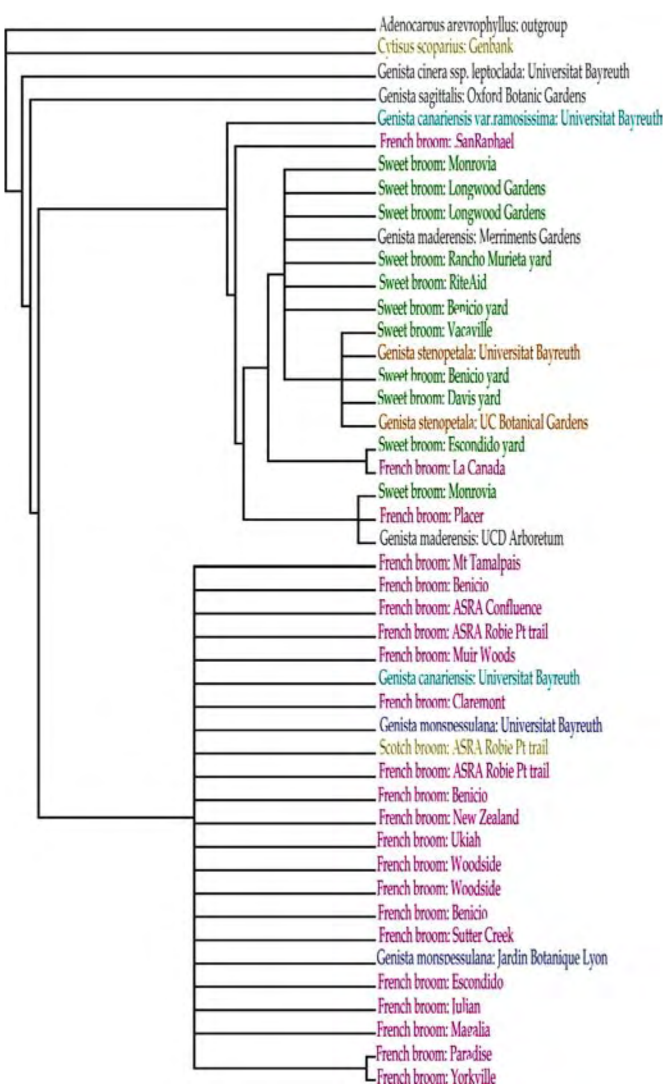
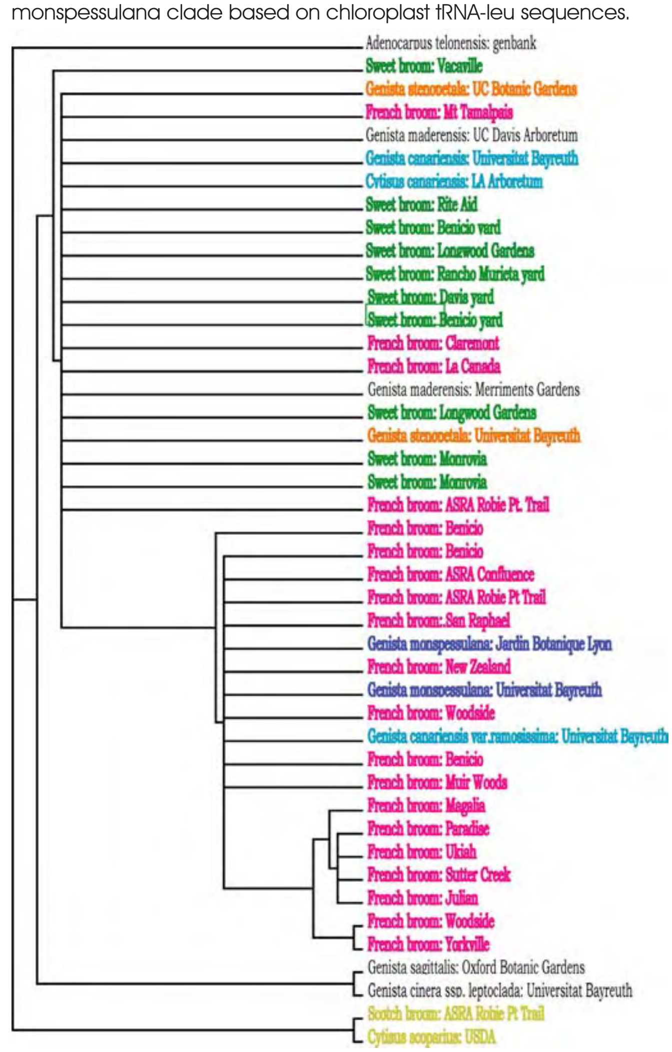


Figure 2

50% majority rule maximum parsimony consensus tree of the monspessulana clade based on chloroplast tRNA-leu sequences.



Assessing the Effects of *Foeniculum Vulgare* on Seedling Germination, Soil Legacy Effects and Restoration Strategies

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ABSTRACT

Fennel (*Foeniculum vulgare*) is an invasive plant that dominates disturbed environments and is suspected of suppressing the germination of other species. Ecological restoration often involves controlling non-native plants, but sometimes the impact of these plants can remain in the soil as a legacy effect, which makes restoration challenging. To evaluate different restoration strategies and the importance of plant communities on soil characteristics, we conducted a reciprocal planting experiment with various treatments within two habitat types— fennel-dominated areas and native Purple Needlegrass (*Nassella pulchra*)-dominated areas. Soil samples were analyzed for conductivity, texture, pH, available nitrogen, phosphorus, potassium and organic matter. Lab analyses revealed little difference in conductivity, texture and pH among the treatments. Fennel soils had higher phosphorus and available nitrogen and lower potassium levels than *N. pulchra* soils. Germination of *N. pulchra* was greater in cut fennel and topsoil removal plots than in other treatments. Fennel and *N. pulchra* germination was low in uncontrolled fennel. In *N. pulchra* plots, fennel had the highest germination. These findings suggest that fennel inhibits germination of *N. pulchra* and itself through factors other than changing soil characteristics and controlling the fennel would be a sufficient restoration strategy.

INTRODUCTION

This study investigates the potential legacy effects of fennel on soil characteristics following its subsequent removal. A study by Keeley (1993) concluded that the majority of degraded habitats cannot be fully restored, but soil analyses can be used to determine which areas would yield the most successful restoration efforts. Our study incorporates this soil analyses concept and addresses potential problems lingering in the soil that may arise during restoration efforts to repopulate previously fennel-dominated areas with native plant species.

The field component of this study took place in a degraded grassland called South Parcel, which is property of the University of California campus in Santa Barbara. Previous research conducted by the Cheadle Center for Biodiversity and Ecological Restoration (CCBER) and the D'Antonio Laboratory have evaluated differences in soil characteristics between sections of South Parcel that are dominated by fennel or *N. pulchra*. In the initial lab analyses, soil conductivity under fennel was twice as high as the soil in adjacent *N. pulchra* a grassland. The pH was also higher in fennel-dominated areas, while carbon and nitrogen were lower. The field experiment was created to determine the biological significance of these differences.

METHODS

A reciprocal planting experiment was conducted among fennel-dominated areas and *N. pulchra*-dominated areas at South Parcel. Fennel and *N. pulchra* seeds were collected from local genotypes, counted and sorted for viability. Two hundred seeds each of both species were planted in six replicate, caged plots for five different treatments: 1.) Intact *N. pulchra*, 2.) Intact fennel, 3.) Cut and controlled fennel and 4.) Cut and controlled fennel with three inches of topsoil removed. The purpose of cutting and controlling the fennel was to see if removing competition and effects of the living plant tissue (e.g. fog collection) would make a difference in seed germination. The purpose of eliminating the top three inches of soil was to evaluate the subsoil for germination potential and to eliminate as much of the fennel seed bank as possible prior to planting. All plots were at least 38 cm x 76 cm or slightly larger and hand-weeded prior to planting. Half of the plot was seeded, while the other half was unseeded to provide a control comparison to account for natural germination of fennel or *N. pulchra*.

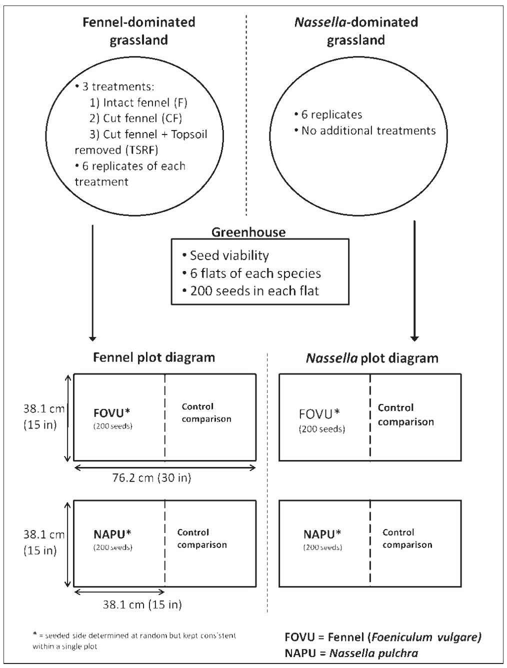

Figure 1 (at left)

Experimental layout of treatments and plots. Each fennel treatment contained 6 replicates with 2 cages each. N. pulchra had 6 replicates with 2 cages each and no additional treatments.

The fifth treatment involved evaluating the germination viability of both species. We seeded six greenhouse flats with fennel and six flats with *N. pulchra*. All outdoor treatments were protected with 76 cm x 38 cm x 10 cm hardware cloth cages and anchored with sod staples to prevent seed predation by rodents and birds. Cages were also placed over the indoor greenhouse flats to provide consistency among all the treatments.

On December 14, 2008, soil samples were taken from all outdoor plots at a depth of 6 inches and oven-dried at 100°F for 24 hours. The soil was then ground, sieved and analyzed for conductivity, texture, pH, total Nitrogen,and total Carbon. Soil samples were also sent to the ANR lab at UC Davis to analyze for plant-available nitrogen, phosphorous and potassium. From March 23 to April 1, 2009, all field plots were monitored. The seedlings of *N. pulchra* and fennel were counted within the seeded and non-seeded halves of the plots.

RESULTS

Soil Analyses

Contrary to our predication that fennel alters the physical and chemical characteristics of soil, we found that fennel-dominated areas and *N. pulchra*-dominated areas were similar in terms of pH, conductivity, texture and organic matter.

The percent carbon and nitrogen in fennel and *N. pulchra* treatments have equalized since the initial soil study. In Figure 2, intact fennel, intact *N. pulchra* and cut fennel have similar levels of carbon content, while cut fennel plus topsoil removed is significantly lower. Removing the first three inches of topsoil has reduced the amount of carbon by approximately half ($p < 0.012$). The same trend is reflected in nitrogen levels and the C/N ratio (data not shown).

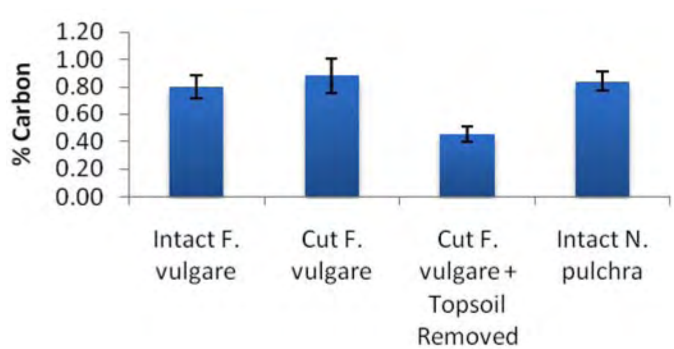

Figure 2

Soil carbon content within each treatment.

The data provided by the ANR Lab at UC Davis indicates that the amount of available nitrogen, phosphorous and potassium is lower in *N. pulchra* soils than in fennel soil (data not shown).

Seedling Germination

Higher numbers of *N. pulchra*-germinated in the treated fennel plots compared to the number of fennel germinants in those same plots. In Figure 3, *N. pulchra* is equally successful in cut fennel and cut fennel plus topsoil removed. *N. pulchra* does significantly better in these treatments than in intact fennel and intact N. pulchra ($p < 0.0001$). Germination of fennel is more successful, though not significantly, within intact *N. pulchra* plots than within any of the treated fennel plots.

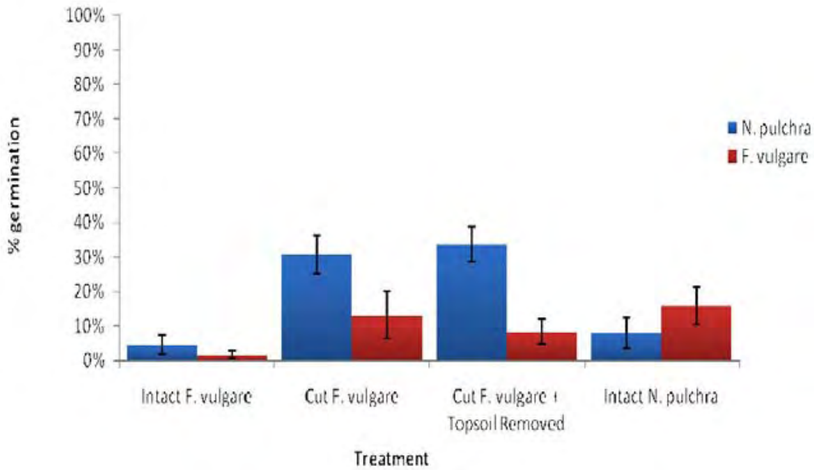

Figure 3

Percent of fennel and *N. pulchra* seedling germination within each treatment.

We monitored all cover in the plots and the highest percent non-native cover is within the cut fennel and intact *N. pulchra* treatments ($p < 0.0001$). However, most of the non-native cover was not fennel but other non-native grasses and forb species. Cut fennel plus topsoil removed has the lowest non-native cover ($p < 0.0001$), which is most likely a result of removing the non-native seed bank.

DISCUSSION

Contrary to our hypothesis that fennel alters soil properties and would inhibit the germination of *N. pulchra*, our results suggest that the soil in fennel plots and *N. pulchra* plots are very similar. Any differences from the initial research may be due to seasonal fluctuations in aerosol inputs, plant uptake or nutrient release from litter. Surprisingly, *N. pulchra* had the lowest germination within *N. pulchra*-dominated areas, probably due to low nutrient levels. The reasoning behind this may be that *N. pulchra* is more efficient in the uptake of nutrients and nutrient return from decomposing litter is slow, resulting in a habitat too low in nutrients to support the establishment of *N. pulchra* seedlings. Empty seed hulls observed within the plots suggests that consumption by insects may also be a cause of low overall germination of *N. pulchra*. In cut fennel and cut fennel + topsoil removed soils, the high nutrient levels (plant-available nitrogen, potassium and phosphorous) may have provided a surplus of nutrients for *N. pulchra* seedlings, resulting in their higher germination. For the intact fennel plots, shading effects may be the determining factor on the low germination of *N. pulchra*.

The implications for restoration strategies are still complex and must be tailored to different plant communities within a site. The similarities between fennel and *N. pulchra* soil characteristics at South Parcel suggest that there are no soil-induced barriers to prevent native plants from being established after fennel removal. Furthermore, since germination of *N. pulchra* is equally successful in cut fennel and cut fennel plus topsoil removed, topsoil removal is not required for successful germination of *N. pulchra*. Removal of fennel (along with seeding of native species in this study) may be a sufficient strategy to promote the growth of native plant species, although competition from other invasives will be higher where the seed bank in the topsoil has not been removed. The use of herbicide in dense fennel stands—where there are no native plants present—will be more efficient and less labor-intensive than chopping and digging. However, fennel eradication may prove to be a process of removing one noxious weed and replacing it with another (Dash and Gliessman 1994). This has been observed in the field as an increase in invasive grasses. Therefore, seeding and planting with native species must be done immediately after fennel removal to prevent other invasives from becoming established.

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Evaluating the Seed Bank of a Disturbed Site to Determine Potential Ecological Restoration Strategies

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South Parcel is a 69-acre area receiving University of California Santa Barbara funding for restoration by the Cheadle Center for Biodiversity and Ecological Restoration (CCBER). It is hypothesized that removing the top three inches of soil could reduce exotic seed abundance. At South Parcel, community types are dominated by mustard (*Brassica nigra*), fennel (*Foeniculum vulgare*), pampas grass (*Cortaderia jubata*), exotic grasses or native purple needlegrass (*Nassella pulchra*). To analyze seed bank characteristics, two soil samples were collected from twelve locations per community (surface to three inches and three to six inch depth) and samples were spread on trays in a green house to allow seed germination. Seedlings were counted and removed following identification. Soil samples were collected and analyzed for conductivity, texture, pH, available nitrogen, phosphorus and potassium. Mustard had highest nutrient levels, fennel had low potassium and nutrients were otherwise fairly constant. Pampas grass and mustard had the highest pH, conductivity did not vary much and there were no significant differences in soil texture (except sandier soils in pampas grass). Seed bank analysis showed much lower seed density at three to six inches depth compared to surface soils. Except for patches in exotic grass habitat, native or perennial species were rare in all sites and depths and pampas grass communities had the highest diversity of native and non-native species. With greatly reduced seed abundance lower than three inches in the soil, removing topsoil could be an effective restoration strategy to reduce non-native species abundance and allow planted native vegetation to establish.

Does Seed Source Matter in Post-Fire Restoration of *Elymus multisetus* in the Great Basin?

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The goal of this investigation is to examine whether *Elymus multisetus* (M.E. Jones) seedlings from local-wild sources outperform regional-farmed sources in post-fire field establishment trials in the Great Basin. *Elymus multisetus* (big squirreltail) is a perennial grass found throughout the western U.S. Both *Elymus multisetus* and its close relative, *Elymus elymoides*, have been identified by the Natural Resource Conservation Service as good revegetation candidates and both are now in commercial production. A primary concern of revegetation in the Great Basin is suppression of *Bromus tectorum* (cheatgrass). In field evaluations, squirreltail has demonstrated an ability to successfully compete with cheatgrass. The Bureau of Land Management encourages the use of native seed in post-fire revegetation and has included both *E. multisetus* and *E. elymoides* in revegetation seed mixes. In the last decade, restorationists have begun to move one step further by seeking the preservation of local adaptation and evolutionary potential in restored plant populations. Both the National Park Service and US Forest Service have policies that encourage the use of local seed or seed from similar environmental conditions to the proposed revegetation site.

So, is there evidence for local adaptation in Elymus populations in the Great Basin? To date, there have been no reciprocal transplant experiments to this effect. In the neighboring Sierra Nevada, reciprocal transplants of *E. elymoides* demonstrated fitness differences that varied with 1000 feet in elevation as well as landscape level W-E aspect. Across the western U.S., squirreltail populations exhibit both high genetic and phenotypic variation. Therefore, the basis for local adaptation exists.

This field experiment is designed to evaluate whether fitness differences exist between *E. multisetus* seedlings from local and regional seed sources. In a common garden environment, superior performance of seedlings from the home population relative to the non-local populations would suggest that there is a genetic basis to any differential fitness. As such, it can provide a first look at the possible importance of local adaptation in a species complex that holds both ecological and managerial importance in the Great Basin.

Site Information

The field site is located on the Hallelujah Junction Wildlife Refuge, near Bordertown, Sierra County, CA. Elevation is approximately 5000 feet. The site is managed by California Department of Fish and Game. It has been rotationally grazed for over 50 years. However, the study area has not been grazed since before a moderate intensity fire in 2007. The plant community is dominated by *Artemisia tridentata* (big sagebrush). While cheatgrass exists at the site, there is not wholesale conversion, as is seen in other sites with extended grazing history in the Great Basin.

Methods

On 20 November 2008, 250 seeds from four seed sources (1000 seeds total) were directly sown in the field. Seed sources include the following: Local–G0 collected within 0.25 mile of the study area; California–G0 collected from Tehama County, CA and G1 farm-grown in Yolo County, CA; Oregon–G0 collected from Jefferson County, OR and farm-grown in Franklin County, WA (generation status unknown); Idaho–G0 collected from Gem County, ID and G1, G2 and G3 farm-grown in Utah County, UT. Prior to planting, there was no pregermination treatment (i.e. priming). Each seed was weighed and then glued to a toothpick for sowing and tracking. Seeds were planted in a complete randomized design and spaced one meter apart. During sowing, some seeds were physically touching an extant plant. To facilitate subsequent analysis of competition effects, competition status was noted for each affected seed.

Phenology, growth and survivorship measurements were taken from November 2008 through September 2009. Seedling emergence was tracked weekly from November 2008 through April 2009. Survivorship was monitored monthly from April to September 2009. Measurements of leaf length and quantity were taken monthly during the active growing season May toSeptember 2009. Since leaf length is strongly correlated to aboveground biomass, it served as a proxy for biomass. Due to the large number of germinating individuals, a random subsampling of leaf measurement was conducted in May and June. By July, the number of surviving plants was severely reduced and a census was conducted.

All analysis was performed in JMP 7.0.2 (SAS Institute, 2007). Outliers with values exceeding three standard deviations from the mean were excluded from analysis. Emergence and survivorship data were analyzed with both univariate and multivariate χ^2 tests. Means of seed weight, emergence date and monthly leaf length measurements (May, June and July) by seed source were compared using student's t test. For each of these five measurements, ANOVA was also conducted, with seed source as a fixed factor. For emergence date, seed weight (random) and competition status (fixed) were added to the ANOVA model. For leaf length, days to emergence (random) was also included.

Results

Seed weight varied significantly by seed source ($p=0.001$). While seed weight differences between sources may result from maternal, non-genetic, effects, the range of seed weights was still relatively narrow—0.001-0.007 grams. Oregon and local sources exhibited the lowest mean seed weights.

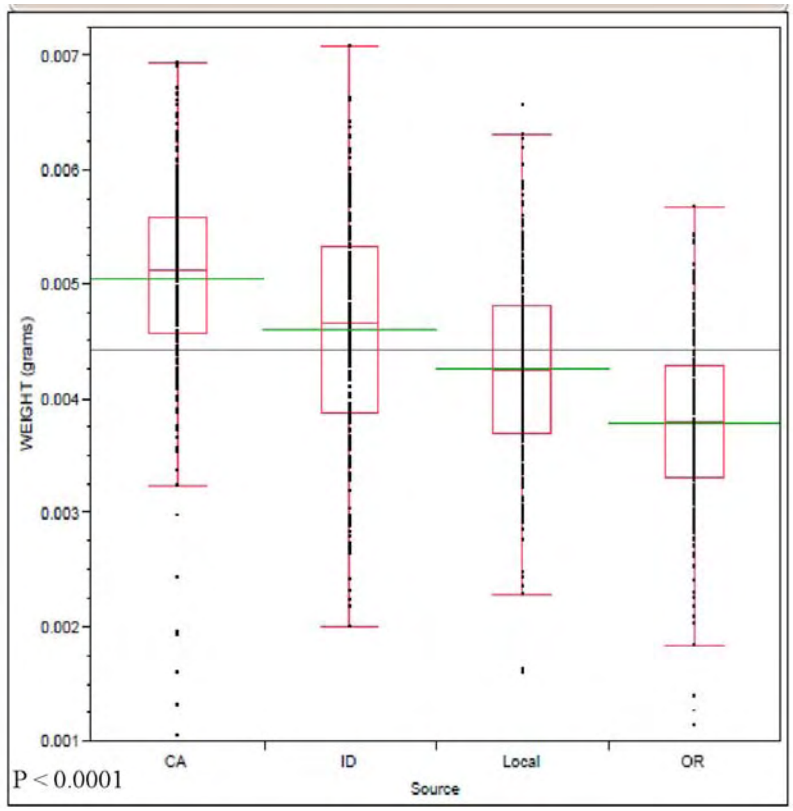
There was higher emergence percentage for seeds from the local source (p <.0001) and with higher seed weight (p=.0006). Local seeds emerged earlier (p <.0001). Competition at time of sowing resulted in earlier emergence (p=0.0015). Seed weight did not affect emergence timing (p=0.0689).

For survivorship through July, there was higher survivorship for seeds from the Oregon source (p =0.0084) and with lower seed weights (p=0.0466). Survivorship through September did not vary significantly by seed source, seed weight, emergence date, or competition status. However, by September, many seedlings may be exhibiting dormancy rather than mortality. It was observed that many seedlings died back in early July, which corresponded to dieback of other perennial grasses in the study area. July dieback may signify the end of the active growing season rather than seedling mortality. In winter 2009, there will be a follow-up census to capture any additional seedling survivorship.

In July, average leaf length varied significantly by seed source (p=0.0411). Seedlings from the Idaho source exhibited the greatest mean leaf length, while those from the local source exhibited the lowest mean leaf length. However, when looking at total leaf length of all plants alive in July, the Oregon source produced the greatest total leaf length. Leaf length observed in May and June showed similar trends by seed source.

Discussion

This experiment provides only mixed support for the possibility of local adaptation in *Elymus multisetus* in the Great Basin. Relative to regional sources, seedlings from the local wild source exhibited greater emergence, earlier emergence dates and lower spring mortality. However, local seeds experienced high summer mortality, resulting in relatively poor July and September survivorship and produced low mean and total leaf lengths. Of the regionally-collected seed, the Oregon source exhibited the highest survivorship through both July and September as well as the greatest total leaf length–a strong correlate to biomass.

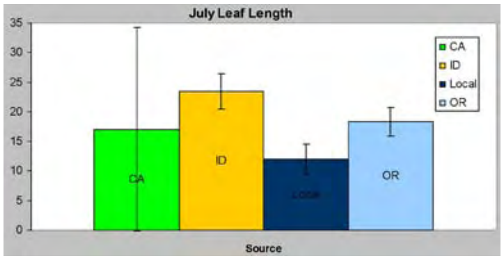


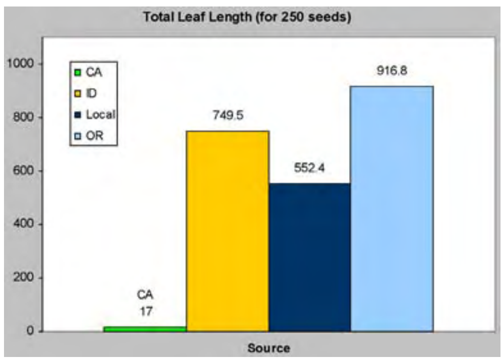
Emergence and Survivorship Percentages

Source	CA	ID	Local	OR
Plants Sown	250	250	250	250
Plants Emerged	21	142	216	178
% Emergence	**8.40%**	**56.80%**	**86.40%**	**71.20%**
April # of Plants	7	102	188	147
April % Survivorship	33.33%	71.83%	87.04%	82.58%
June # of Plants	2	44	77	74
June % Survivorship	9.52%	30.99%	35.65%	41.57%
July # of Plants	1	33	49	52
July % Survivorship	**4.76%**	**23.24%**	**22.69%**	**29.21%**
Sept # of Plants	0	8	5	10
Sep % Survivorship	**0.00%**	**5.63%**	**2.31%**	**5.62%**

While these data do not paint a clear portrait of local adaptation, it can still be inferred that seed source is an important factor in seedling establishment and performance of *Elymus multisetus*.

SOURCE	Mean Emergence Date		Comparison of Means (student's t)
CA	3/27/2009	+/- 5 days	A
ID	3/7/2009	+/- 2 days	B
Local	2/28/2009	+/- 2 days	C
OR	3/13/2009	+/- 2 days	D





Mean Leaf Lengths (cm) by Month

	May	May SE	Jun	Jun SE	Jul	Jul SE	Sep	Sep SE
CA	5.4	+/-1.4	8.2		17.0			
ID	7.3	+/-0.8	11.8	+/-2.0	22.9	+/-4.5	31.7	+/-10.0
Local	8.3	+/-0.9	8.0	+/-1.5	11.9	+/-1.3	26.1	+/-6.4
OR	5.4	+/-0.7	11.9	+/-2.3	18.1	+/-2.2	31.6	+/-6.3

Seedling survivorship is an important component of fitness, though long-term survival may data may provide different results. The differential seedling establishment success exhibited across seed sources can be taken as indirect evidence for overall fitness differences between populations. Certain populations may possess adaptive traits that allow for enhanced performance under post-fire revegetation conditions. More testing of the scale of local adaptation in perennial bunchgrasses in the cold desert is warranted. Furthermore, the decision to introduce regional, farm-grown seed in Great Basin restoration sites should be accompanied by either review or field evaluation of the performance of each seed source under similar conditions to proposed revegetation site. The introduction of farm-grown seed may significantly impact local population genetics.

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Adapting an Agricultural Technique for Use in Wildlands: Testing Variations on Solarization for Invasive Control in a Severely Disturbed Plant Community

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Abstract

Exotic propagules often greatly outnumber native seeds in the soil seed bank of invaded plant communities. This makes restoration very difficult, often requiring multiple years of invasive species management to establish native species. Solarization, a technique used in agriculture, places clear plastic over moist soil during the summer. This heats the soil as high as 55° C, killing weed seed. Two studies used variations of the method successfully in a wildland setting. One study used irrigation and clear plastic during the summer, while another applied black plastic during the winter with no irrigation. Our goal was to compare the success of plastic color (black, clear and no plastic), season of application (winter and summer) and level of soil disturbance

(tilling, scraping and no disturbance) in reducing exotic weed seeds in the seed bank. Plots were not irrigated. Preliminary results show that clear plastic placed in the summer controlled the most species. Black plastic winter treatment did not control exotic broadleaf species as well as clear plastic. The study shows that combinations of winter and summer solarization with black and/or clear plastic provide a range of techniques for managers who need an alternative non-chemical invasive control method in invaded plant communities.

Introduction

Controlling exotic invasive species is of the most challenging conservation issues for management of wildlands in many regions of the US. In invaded sites, seeds of exotic species may greatly outnumber seeds of native species. Coastal sage scrub (CSS) communities can have exotic seedbanks 40 times larger than native seedbanks (Cox and Allen 2008) and disturbed CSS communities do not usually recover from disturbance (Stylinski and Allen 1999 and Allen et. al. 2005). Further difficulties controlling exotic plants may be encountered if land managers are limited in their ability to use herbicides or fire because of potential environmental impacts.

Solarization is a technique used in agriculture for controlling invasive species. In the traditional implementation of solarization, the soil is tilled, irrigated and covered with clear plastic. This heats the top layer of soil, killing seeds and pathogens. However, some aspects of implementation may be problematic in wildlands, where tilling soil may not be desirable and water for irrigation may not be available.

Modifications of the technique have been used successfully in wildland restoration in southern California. One study used hand cultivation instead of mechanical tilling (Moyes et. al. 2005); another used black plastic during winter when soil is naturally moist (Marushia and Allen 2009). Our goal was to compare the success of black versus clear plastic, season of application and type of cultural treatment (raking, tilling, mowing) for reducing the amount of exotic seed in the seed bank and allowing the establishment of natives. In addition, we wanted to implement the technique without the use supplemental irrigation as this more feasible in wildland situations, but may limit the effectiveness of the technique.

Methods

Plots were set up at Motte Rimrock Reserve, a University of California Natural Reserve in Perris, California. The treatment area is a disturbed area dominated by exotic grasses and forbs. The design is a randomized complete block that tests three soil preparation treatments, three plastic treatments and two seasonal timing treatments. Four replications were installed.

- The three soil preparation treatments are: 1.) weed-trimming/mowing (no soil disturbance) 2.) raking or hoeing treatment to remove existing vegetation with limited soil disturbance and 3.) rototilling/discing to simulate agricultural disking.
- The three plastic treatments are: 1.) black plastic, 2.) clear plastic and 3.) no plastic.
- The two seasonal treatments are: 1.) early season/winter treatment and 2.) late season/spring to summer treatment. The early season treatment was initiated the first week of February, 2008 and left for at eight weeks. The late season treatment was installed in April 2008 in an attempt to retain residual soil moisture from winter precipitation, as the area typically receives no precipitation from April to October. The plastic was left in place through August to take advantage of the highest summer temperatures.

After the plastic was removed the plots were divided into subplots and half the subplots were seeded with locally collected native seed in fall 2008. Since there was not an observed seeding effect, plots will be reseeded in fall 2009. Data was collected during spring 2009 and will be collected again in spring 2010. Response variables to be measured are percent vegetative cover by species, species density and species diversity.

Results and Discussion

Exotic grass cover was reduced significantly in all treatments compared to the no plastic, winter, mowed treatment. The clear plastic, summer treatments had less than 1% mean cover of exotic grass. However, they were not significantly different from the other treatments of either plastic, color or season. Though not significant, summer treatments of both colors reduced cover of grass more than winter treatments. *Bromus rubens* was the most common exotic grass on site.

Data for the exotic and native forbs is more difficult to interpret. Both functional groups occur in low numbers when exotic grass is present, but their cover increases when the grass is removed. To test the effectiveness of the treatments separately from the effects of grass competition, we analyzed data for the forbs in the scraped and tilled plots only.

The clear plastic treatment in the summer significantly reduced the cover of exotic forbs compared to all other plastic and season combinations in the scraped and tilled plots. Mean percent cover in the clear plastic summer plots was less than 5%. The primary species of exotic forb present was *Erodium cicutarium*.

Native forbs in both the summer clear and black plastic treatments had significantly lower percent cover than the winter treatments. This suggests that the solarization summer treatments were more effective in controlling the seedbank. Native species cover was highest in winter-treated scraped and tilled plots, particularly in those covered with black plastic. This further indicates that the winter treatments did not kill the native seed in the seed bank. Future seasons will help determine how quickly the exotics reappear from the seed bank and whether winter treatments might be beneficial to the vegetative community.

Since a successful solarization treatment would reduce the natives in the seedbank, subplots were seeded with seed collected on site. However, precipitation was low in the growing season following solarization and no seeding effect was observed.

In summary, using clear plastic in the summer over scraped or tilled soil reduced the plant cover for all functional groups (exotic and native forbs, exotic grasses) after the first season. This suggests clear plastic reduced the seed bank and may be useful for restoration of heavily invaded plant communities. A second season of data collection will aid in determining whether the effect is longer term than one growing season.

The clear plastic summer treatment appears to have provided successful control even though soil was dry at the time of application and therefore less likely to conduct heat energy.

Because solarization techniques were developed for agriculture, irrigation is considered necessary to the success of solarization. These results are useful for wildland managers because they show that clear plastic in the summer will be useful even in relatively dry soil.

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Contributed Posters

Time and Temperature Requirements for Thermal Death of Seeds of Yellow Starthistle (*Centaurea Solstitialis* L.)

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We determined the time required for mortality of seeds of yellow starthistle (*Centaurea solstitialis L.*) at constant temperatures of 46°, 50°, and 60° C. Seeds were placed in organdy bags and allowed to imbibe water at room temperature for two hours before heat treatment. Seed bags were placed in jars filled with sand wetted to field capacity and maintained at constant temperature in a water bath. After removal from the jars, seeds were incubated in a growth chamber and germination percentages were determined after 14 days. The time to 100% mortality was 48 hours at 46° C, 16 hours at 50° C, and 0.5 hours at 60° C.A tetrazolium test was performed on seeds with intact seed coats that had not germinated to determine viability. At sampling times with 100% mortality, no seeds tested as germinable. Nonlinear models for seed mortality as a function of duration of heat treatment were developed. These models have potential applications for predicting mortality of yellow starthistle seeds in management strategies that rely on high temperatures, such as burning or solarization.

Invasive Aquatic Weeds: Implications for Mosquito and Vector Management Activities

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Abstract

Healthy natural wetlands are far less likely to be breeding areas for disease-carrying mosquitoes than degraded ones. Degradation of these bodies of water by invasive aquatic weeds and other influences can result in their being potential habitat for mosquitoes that can carry the West Nile Virus, encephalitis and other diseases. Control of these invasive plants can be an important part of the Integrated Weed/Pest Management efforts of both Weed Management Areas and Mosquito and Vector Control Agencies. Adverse effects of Water Hyacinth, *Eichhornia crassipes*, hydrilla, *Hydrilla verticillata*, Water Evening-primrose, *Ludwigia* spp, Smooth Cordgrass, *Spartina* spp., *S. densiflora* x *foliosa*, and other species on water quality and facilitating mosquito breeding will be shown. Presentations on the importance of S. spp. in San Francisco Bay were made at recent statewide Cal-IPC and Mosquito and Vector Control Conferences. Demonstration of these relationships can enhance both agency and public awareness of their importance.

Introduction

The adverse effects of invasive aquatic and riparian weeds on water quality; hydrology, native plant communities and wildlife habitat and their consequences for mosquito control efforts, public health and nuisance problems, while implied, could be better articulated. Over the years, I have become increasingly aware of these relationships. In 2005, I was appointed to the Mosquito and Vector Management District of Santa Barbara County (MVMDSBC). In pursuit of these activities, I became increasingly aware of the effects of invasive aquatic weeds in favoring the breeding of potentially disease-carrying mosquitoes and interfering with vector control efforts. I also became aware of successful collaborative activities among governmental agencies and a variety of natural history and weed management. I will begin with a brief discussion of how concepts of Integrated Pest Management apply to mosquito control. I will then illustrate specific invasive plants and problems they present. There will be examples of on-going successful collaborative efforts; then conclusions and recommendations.

Integrated Pest Management in Relation to Mosquito Control

Successful control of larvae and pupae is the primary emphasis, greatly reducing the need for aerial spraying. Predators – native species in natural habitats and introduced predators, (especially Mosquito Fish, *Gambusia affinis*) in artificial ones – are important. Biorational larvicides, such as *Bacillus thuringiensis* ssp. *israelensis* (Bti), *Bacillus sphaericus* (Bsp) and maturation inhibitors such as IGR/JHA-Methoprene distributed as granules or briquettes, serve to reduce larval populations, supplementing the effectiveness of predators. Waterways degraded by invasive weeds tend to promote mosquito breeding and interfere with predator activity. Control of invasive aquatic plants improves water quality, discourages mosquito breeding and enhances predator effectiveness.

Freshwater Invasives

Water Hyacinth, *Eichhornia crassipes*, and 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).

Giant Reed, *Arundo donax*, is a major riparian invader (DiTomaso and Healy 2007) and although not considered an aquatic invader, it does leave residual standing water that is considered a significant mosquito breeding source. Because of the resultant flooding, wildlife habitat degradation and water wasting effects there have been some very effective major watershed-wide control projects. The more effective of these projects have involved coordination with a wide variety of state and federal agencies. In addition to their value in reducing mosquito breeding areas, they can be important models in developing the relationships important in mosquito control as well.

Among the more effective watershed-wide efforts is the work done under the direction of Jason Giessow in the Santa Margarita-San Luis Rey Weed Management Area. Over a twelve-year period his firm is achieving great results in *A. donax* control. The necessary permits, Memoranda of Understanding (MOUs) and where needed, land owner agreements are obtained for the entire watershed, saving time and expense. The physical work begins in the fall to avoid migratory bird breeding season. The twenty to forty-foot canes are separated from the native vegetation and treated with an aquatic-safe glyphosate compound. In December and January, the dead material is chopped in place, serving as mulch and eliminating the need for removal and disposal. In the spring, replacement natives are planted, roughly half Mule-Fat, *Baccharis salicifolia*, and other fast growing riparian species. For the next three years, re-sprouting shoots are treated as they emerge. Later, previously treated areas are inspected every five years. I have personally visited these areas and can attest to their effectiveness in weed control and aesthetic and habitat results (Santa Margarita-San Luis Rey WMA 2000 and Cal-IPC Poster 2001). Similar results are being achieved in Arundo Teams elsewhere in California.

Saltmarsh Invasives

In estuarine habitats, Smooth Cordgrass, *Spartina* spp., especially the hybrid *S. densiflora* x *foliosa* (Ayres et al.2007), near-shore salt marshes displaces native species, invades deeper waters and inhibits 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 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 invasive 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 (Olson 2000 and Invasive Spartina Control Project).

This agency in one of the oldest mosquito control agencies in the United States of America. Particularly because of problems with the Saltmarsh Mosquitoes, *Aedes* spp, efforts on its formation began in 1904. Under the 1915 Mosquito Abatement Act, two separate districts were formed which merged in 1953. This district has long been a leader in mosquito and vector management. The Invasive Spartina Project has been one of its successes and can be an example for other agencies to follow.

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, *Salicornia virginica, Frankenia salina* and native cordgrasses (Invasive Spartina Control Plans 2008). Imazapyr was recently approved for aquatic use in California. It is much more effective than glyphosate (Rodeo) on Spartina (Kilbride & Pavegilo 2001). Activities were timed to avoid nesting Clapper Rails, *Rallus longirostris* 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, personal communication 2008). 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.

Summary and Conclusions

1. Invasive aquatic and riparian weeds are a major threat to waterways, displacing the native vegetation that supports wildlife. They also degrade water quality and availability and increase the risk of disease-carrying and nuisance mosquitoes. They also interfere with mosquito control efforts.
2. Control of these invasive plants enhances wildlife, water quality and aesthetic values as well as assisting mosquito control efforts. Public appreciation of these activities has been gratifying.
3. Collaboration among agency and non-governmental weed control and vector control organizations can result in satisfactory and cost-effective outcomes. Examples of successful programs have been discussed.
4. Since Water Evening-primrose *Ludwigia* spp., is becoming a major problem in many parts of California, perhaps Ludwigia teams along the lines of the Arundo and Spartina teams, with the involvement of mosquito and vector management districts could achieve similar results.

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The San Francisco Estuary Invasive Spartina Project; www.spartina.org

Using Smart Phones and Citizen Scientists to Map Invasive Species and Track Spread Over Time

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Abstract

In 2005, the Santa Monica Mountains National Recreation Area staff completed a comprehensive inventory of nineteen invasive species on all public lands within the boundary of this national park. This field effort involved two full-time staff working for two years and cost approximately $250,000. Although this map serves as an excellent planning and education document, it was quickly out of date due to both our own and partners' treatment efforts and the continued spread of many of our target species. National Park Service staff are now working with scientists from UCLA to develop software applications for smart phones that will allow users (citizens and staff) to photograph target invasive species and have these photographs and GPS locations uploaded and displayed as a map on a public webpage (whatsinvasive.com). We are hoping to use this technology to educate and involve the public in invasive species work, track the spread of target invasive species and identify plant populations for control as part of an early detection and rapid response program. During a two-week trial run working with park staff carrying out other duties (tracking wildlife, maintaining roads and trails, inventorying fuel modification treatments), we located 811 infestations of six target species. We overlaid these points on our existing weed map and found significant population expansions in the majority of the species. We are now expanding the program and hope to involve the general public via phone applications, the website and other programs within the coming year.

Introduction

One of the first steps in many weed management programs is to map the occurrence of invasive species infestations within a particular management area. These maps allow managers to identify the extent of the invasive species problem, look for threats to high priority areas or conservation targets, develop budgets, create timelines and generate grant proposals for weed control. One unfortunate aspect of weed maps is that they typically become out of date quickly due to either continuing expansion of invasive species into new areas or effective control work removing them from areas. Although many organizations have developed tools to monitor invasive species population expansion or contraction over time (e.g., The Nature Conservancy's Weed Information Management System), other weed maps are static tools that are snapshots rather than dynamic documents. For these snapshot maps, a simple and cost-effective way to get updated weed distribution information is greatly needed. An additional need for many land managers is an efficient way to utilize staff or volunteers in the early detection of invasive species. Numerous studies show that detection and removal of invasive species infestations when they are small (under one hectare in size) increases the likelihood of treatment success and reduces treatment cost.

In order to address management needs for updated weed distribution information and to develop a citizen science method for early detection of weeds, the National Park Service Santa Monica Mountains National Recreation Area partnered with scientists at the University of California Los Angeles Center for Embedded Networked Sensing (CENS) to develop invasive species mapping cell phone applications. In the joint project described here, CENS and NPS worked in partnership to develop a cell phone application that would allow both NPS staff and citizen scientists to quickly and effectively map invasive species that occurred within the park.

Methods

Mobile phones containing digital cameras, microprocessors, GPS receivers and the ability to connect with the Internet through cell phone networks are becoming more common. Mobile phones like Apple's iPhone and others are gaining wide use especially in urban areas such as Los Angeles. These mobile phones contain microprocessors that are capable of running simple applications such as on-line guides, games and music players. Scientists at CENS are exploring ways of utilizing these mobile phone applications in conjunction with their human users to obtain data about our environment. NPS staff provided a list to CENS scientists of target species based on their ecological impact and limited distribution within the park. In addition, NPS staff provided natural history information on these species such as their appearance, flowering and fruiting times and habitats.

This collaboration resulted in the creation of "What's Invasive!", a citizen science invasive species detection campaign found on-line at whatsinvasive.com. The basic elements of the campaign are the mobile phone applications that provide a framework for capturing GPS locations, labeling observations with plant names and storing digital photographs of invasive species, as well as automated upload of data to a designated database. The campaign also includes the Web site that is linked to the database and displays a map of invasive species locations with associated identification tags and photos. Functions on the Web site calculate and display some basic statistics as well as let the users edit and review their own observations.

The current "What's Invasive!" mobile phone application provides users with a choice of six invasive species or an "other" category for labeling their observation, with an optional photo. After the user provides a species label, each observation is automatically tagged with a GPS location. The observation is then stored in the mobile phone for one minute to allow the user to delete the observation before automatic upload to the database. If the mobile phone is not in an area of good connectivity, or the user selects to disable automatic upload, the observations are then stored indefinitely until the user re-establishes connectivity.

For the field trial of this project, we provided eight park staff with "smart phones" running a version of the "What's Invasive!" application. We provided a one-hour training in using the mobile phones, taking pictures and identifying the six target invasive species. We also provided each staff member with a pocket photo field guide to the six species. Staff participating in the field trial were from a wide variety of backgrounds and included two maintenance staff, two wildlife biologists, two plant biologists and two education staff. These staff were asked to carry the phones with them for two weeks and take pictures of these six species whenever they encountered them within the park boundaries. They were also asked to plug in the phones at the end of each day to charge their batteries and automatically upload the digital photos and GPS locations. Maps of invasive species locations and graphical displays of summary statistics were then updated automatically on the webpage (Figure 1). This constant updating provided instant feedback to project participants on how the campaign was functioning and their own contribution to the campaign.

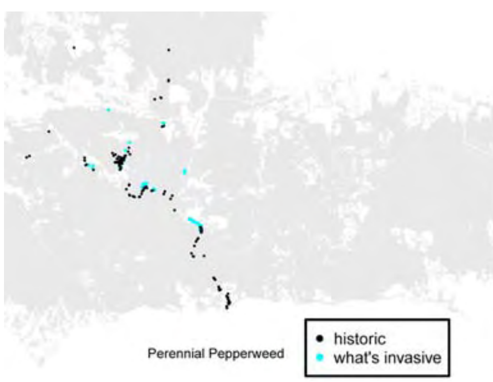
Results

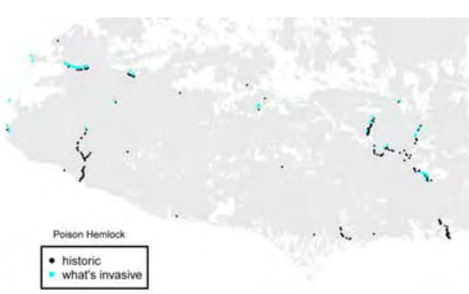
Over fourteen days with eight users in the field taking pictures as they did their jobs, we collected 811 locations of the six target species. This is almost one quarter of the infestations detected over a two year survey period in 2006.

Figure 1

Example of summary statistics found on the What's Invasive webpage

These locations were overlaid on the prior invasive species map completed in 2006 to look at distribution changes over time (Figure 2 and Figure 3). These maps show that participants detected many populations that were found during the 2006 survey, thus confirming the ability of the participants to correctly identify species (2006 data was collected by trained botanists). Comparison of 2006 and 2009 maps also show significant population expansions in many areas (Figure 2 and Figure 3).





Issues identified during the pilot included the limited battery life of the mobile phones (average of four hours). During the pilot we provided participants with car chargers so that phones could be charged while in or near the car. The application also did not allow for entry of distributional information. For example, observers were unable to record whether the infestation was a single individual, a small patch, or a huge field. However, because of this desired feature and the close communication between the NPS staff and CENS scientists, the newest version of the software has this capability. Most of the photos were taken close-up to confirm species identity which prevents giving a broader, infestation view of the population.

Discussion

This approach to invasive species early detection and weed mapping has great promise for areas with good GPS coverage and users that own smart phones. We collected a large amount of data over a short time period, demonstrating the utility of this approach. Benefits of this approach include the collection of digital photographs allowing park staff or other volunteers to validate species identifications prior to going into the field. The inclusion of continuous tracking of participants' location while the cell phone application is in use allows tracking of where participants went and did not detect invasive species, although this does not rule out the existence of these species in the area. The automated uploading, processing and mapping of points allows land managers to view a consensus map and use the detection by multiple observers to confirm the presence of an invasive species in a particular area. Finally, this type of citizen science campaign also plays an important educational role as park users become more aware of invasive species. Future work will include more field trials with volunteers, updates to the software and a full public launch of the application and website.

Camp Pendleton's Rapid Response Non-native Invasive Plant Species Program

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Marine Corps Base Camp Pendleton initiated an Emergency Non-native Invasive Species (NIS) Plant Control Program in 2005 to rapidly control incipient weeds and weed populations in small areas with high ecological and/or training value. Contractors on base working with Camp Pendleton's Land Management Branch are required to report new populations of NIS they may observe; a weed reporting form is provided in the appendices of statements of work.

Camp Pendleton faces many incipient NIS difficulties. NIS propagules have the potential to be introduced by vehicles coming in from exotic locations, recent construction, wildland fires and dispersal through the I-5 corridor. Treatment must be done around busy military training schedules in a timely manner. Risk assessment, prioritizing existing incipient NIS for treatment and forecasting future NIS problems is always a challenge. To address some of these difficulties in the future, roadside and construction area monitoring and treatment projects are being developed to complement the Emergency NIS Program.

Mapping Weeds from the Ground, the Air or Beyond

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Abstract

With advances in remote sensing technology and image analysis techniques, more options are available to weed managers for mapping invasive species than ever before. These new technologies include advances in airborne scanners, higher resolution satellite imagery, sophisticated land-cover mapping techniques and advanced software approaches. To understand and demonstrate the capabilities that these technologies can provide to weed managers, land-based mapping of select invasive species was performed near the Santa Clara River in Southern California and compared to new, advanced remote sensing techniques. Specifically demonstrated was the ability to take advantage of free, readily available natural color band aerial imagery to quantitatively map select invasive species like giant reed (*Arundo donax*). While factors such as spatial resolution, radiometric resolution, revisit frequency, timeliness and purchase cost are important considerations for any remote sensing approach, this project demonstrates the ability to use widely available low cost natural color imagery to accurately, efficiently, and quantitatively map select invasive species over time. The ability to make use of national program imagery products opens the door to cost effective mapping solutions that allow more time, money and effort to be spent on removal and restoration efforts associated with invasive species control.

Introduction

A program to control giant reed on the Santa Clara River in Ventura County is the first part of a 233-acre comprehensive habitat restoration plan. The control program is in the third year of a ten-year program. Program effectiveness monitoring of has been based on field mapping across parts of the site that are dense riparian that is difficult to penetrate. Additionally, since a fall fire in 2003, giant reed rapidly developed over the site after the baseline vegetation mapping was originally prepared but before the plan was approved for implementation. Our field monitoring to date was more qualitative using photo-documentation points. We describe here the use of remote sensing combining imagery from 2005, 2007 and 2009 to increase efficiency of quantitative monitoring for the 233 acre site over the next seven years.

Methods

The overarching goal of the methodology for this project was to utilize ground-truth data collected by plant ecologist to "train" the image analysis software to recognize the presence or absence of arundo at the site. In broad terms, this was accomplished by training the image analysis software to use ground-truth data to derive specific rulesets that characterize the variability of arundo at the site. Rulesets were developed by integrating two techniques: object based image analysis (OBIA) and non-parametric data mining procedures. The combination of these two techniques allowed the development of an arundo ruleset based solely on ground-truth data and satellite image characteristics specific to those ground-truthed conditions.

Investigation into available satellite and aerial imagery for the site footprint produced a number of imagery options available for OBIA analysis. The four imagery options included:

1. National Agricultural Imagery Program (NAIP): Spring 2005 and Spring 2009, 1 meter spatial resolution
2. Ventura County color photography: Fall 2007, 0.3 meter (1ft) spatial resolution
3. QuickBird satellite image: Fall 2008, 0.6 meters spatial resolution panchromatic, 2.4 meter multispectral

To perform the accuracy assessment of the classification with the above imagery, 101 sample points, based on the re-classification of the image, were created across the project area. The sample points were located well within a homogenous polygon and were located in all vegetation classifications represented in the remote sensing analysis. The vegetation classes of the polygons, and subsequently the points, consisted of Arundo, Arundo litter (controlled Arundo areas with Arundo thatch and annual non-native species) and other vegetative species. With ground truth information gathered, data-mining techniques were employed to find the optimal combination of imagery segmentation object characteristics to use for separation of the objects into vegetation classes. Classes were then assigned using the resulting algorithms in nearest neighbor classification. Of the photography, the 2007 color imagery was first to be classified using developed algorithms. Subsequently the 2005 was classified, requiring some on-screen update of ground truth class determinations to account for the temporal differences. Lastly, as soon as the 2009 NAIP imagery came available it was processed in a similar manner. All of the imagery, with the exception of the QuickBird image, was available for free download from their respective distribution sources. The QuickBird image was available for purchase from Digital Globe's imagery archive. All 4 images were obtained, processed and classified for arundo. Results of the analysis are presented in the following section.

Results and Discussion

This project is presently being finalized so complete statistical analysis of the accuracy of the classifications is not complete. However, several factors affect the accuracy of the remote sensing product in identifying and classifying arundo. In this project, ground truth efforts were not coincident with image collection except for the 2009 NAIP image, thereby making extrapolations to previous images more difficult. That said, detailed knowledge of the site combined with photo-interpretive efforts of the historic images allowed a general comparison of classification accuracy. In 2005 NAIP image, arundo was correctly classified nearly 80% of the time when compared to known arundo stands. Lower classification accuracies of arundo (75%) were obtained with the 2009 NAIP image. This lower classification accuracy is likely due to the amount of arundo that had been removed between 2005 and 2007 which left a dense mat of dead or dying vegetation on the ground. The highest accuracies (80%) were obtained from the Ventura county aerial photography. The one foot spatial resolution of this imagery provided additional textural information not available at higher resolutions, facilitating the arundo to willow differentiation. Lastly, the 2008 QuickBird imagery, which has advantage of near-infrared (NIR) band, though the detriment of lower spatial resolution (2.4m multispectral and 0.6m panchromatic) was also evaluated using this method. Even with benefit of the NIR band, which is highly valuable for vegetative studies, the lower spatial resolution of the QuickBird imagery proved to be a greater detriment in that the object-segmentation does not have benefit of high resolution textural information. The arundo to willow differentiation, for instance, was highly dependent on textural differences. Mapping of arundo with high spatial resolution/ low spectral resolution imagery was found to be feasible and more accurate than similar satellite imagery with slightly less spatial resolution.

Diluting the Hybrids: How Much is Too Much?

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Since the hybridization between introduced smooth cordgrass (*Spartina alterniflora*) and native Pacific cordgrass (*S. foliosa*) was first documented by Daehler and Strong in the early 1990s, we have witnessed a population explosion in which cordgrass hybrids crossed with other hybrids and backcrossed to the native species to create a genetically variable hybrid swarm. Hybrid cordgrass threatens tidal habitats through ecological engineering and the native species through pollen swamping. The State Coastal Conservancy's San Francisco Estuary Invasive Spartina Project has systematically removed plants with obvious invasive traits, e.g. tall, robust stems; large inflorescences, etc. as they work to eradicate invasive Spartina from the San Francisco Estuary. In the course of monitoring eradication efforts, we used molecular fingerprinting to test hundreds of cordgrass samples each year. The results of these genetic tests show that highly backcrossed hybrid plants, with no obvious morphological characteristics to distinguish them from natives, are "hiding" in the marshes of the Bay. If not identified and removed, these "cryptic hybrids" may further dilute the native genome. But if they look and behave like natives, is it worth the effort to identify and treat these highly backcrossed hybrids? In working to eradicate invasive Spartina, how should the ISP respond to these "cryptic hybrids"?

Maintaining Riparian Habitats after Initial Invasive Plant Treatments on Camp Pendleton

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Camp Pendleton manages the removal and control of non-native invasive species (NIS) within riparian habitat in four major and ten minor drainages. Following large-scale removal projects of arundo (*Arundo donax*) and salt cedar (*Tamarix* spp.) infestations, the Base maintains these riparian areas through herbicide treatments, active restoration and habitat monitoring.

Following initial treatments, known NIS populations such as perennial pepperweed (*Lepidium latifolium*), arundo, and salt cedar are retreated with foliar herbicides throughout all Base drainages on a rotating schedule. The re-treatment program also serves a dual purpose for monitoring any newly discovered NIS infestations that the contractor encounters within the re-treated drainages. Following newly implemented control methods for the large-scale removal projects, native revegetation methods are being developed to supplement any NIS retreatments. Furthermore, a post-NIS removal monitoring plan implemented in 2009 is being used to track the health and recovery of these treated areas. To date, nearly 900 acres of exotic invasives (primarily arundo and salt cedar) have been removed from Base riparian corridors and nearly 5000 acres of riparian habitat is re-treated annually.

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

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Over the 2008-2009 growing season, *Sinapsis alba* pressed seed meal was tested as a pre-emergent inhibitor of French broom (*Genista monspessulana*) seedlings in oak Savannah/meadow habitat. *S. alba* seed meal, known to contain 4-hydroxybenzyl isothiocyanate, releases a quinone that hydrolyzes in soil to form SCN-, a known bioherbicide. The meal was applied by broadcasting, onto the surface of the soil of six replicate per treatment, one meter diameter circular blocks at a rate of 8.8 kg of SCN-/ha, and 13.2 kg of SCN-/ha. The soil seed bank content, soil fauna and nutrient content of soils was also analyzed. The content of French broom seeds in the soil was 3256/m^2. Twenty four species germinated from the soil samples. Germination was dominated by native species. A significant decrease of broom seedlings was observed in treated plots compared to controls at both levels of application with the greatest inhibition resulting from the higher application rate. No significant differences were found in soil fauna or nutrient content between treated and untreated blocks at the lower application rate, in the soil tested at the beginning or the end of the experiment. However a significant decline in nitrate and phosphorus content of soils was noted in all plots between the soil tested in October and that tested in mid-May at the end of the experiment. Neither treatment level prevented germination of 100 % of broom seedlings in a season with late spring precipitation. This limits its usefulness as a control agent. Considering the effects of the *S. alba* seed meal application rates regarding overall efficacy as an inhibitor of broom seedlings and cost, the 8.8kg of SCN-/ha is recommended as the preferred application rate for those sites where this control may have some utility in inhibiting broom seedlings in small areas where adult broom plants have been cleared but the soil has a rich content of broom seeds in the soil seed bank and use of synthetic pre-emergent chemicals is prohibited.

Birds and Invasive Plants: A Review of Interactions and Management Considerations

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Abstract

Invasive plants alter ecosystems in a variety of ways, most of which are assumed to be detrimental. Ecological effects are one of the criteria used by Cal-IPC to rate invasive plants; however, the effects of invasive plants on wildlife are unknown for most systems. During research for the 2006 Cal-IPC Inventory update, we found few published studies examining direct interactions between birds and invasive plants. For this poster, we reviewed available studies of the relationship between birds and invasive plant species

in California. Available information ranges from qualitative observations to fine-scale GIS-based spatial modeling.

Here we summarize case studies representing a range of invasive plants and avian communities. For some species, strong data shows the negative effects of invasive plants on birds and the benefits of removing weeds. Other invasive plants appear at first glance to have a positive effect on measures such as avian density but may in fact be "ecological traps" that reduce the birds' nesting success. In still other cases, the results are mixed depending on the avian species of interest. Understanding these interactions becomes increasing critical as land managers and policy makers develop long-term plans to buffer wildlife species against climate change, plans that may include prioritizing which invasive plants to remove and where.

Introduction

There is a general consensus that invasive plants are bad for natural systems – but are they all equally bad? Many species of invasive plants pose a severe threat to ecosystems by displacing native plants and altering ecosystem structure and function (Table 1). However, there are surprisingly few studies of interactions between invasive plants and wildlife, positive or negative (Cal-IPC and TWS 2007), despite the fact that in some areas invasive plants have mostly displaced native species. We reviewed published and unpublished reports describing quantitative studies of the impacts of invasive plants on birds in California. Our objective was to determine if any generalizations can be drawn from the available data.

A better understanding of the full scale of direct and indirect interactions may help inform management decisions that take into consideration the full species community within a particular location or habitat. More than 200 species of invasive plants are established in California (Cal-IPC 2006). Where birds use invasive plants, control methods for those plants are designed to reduce impacts on the birds, with removal outside of the breeding season or rapid replanting of native plants. Controversies can arise when removal of invasive plants appears to conflict with avian species' needs, especially when the birds are threatened or endangered. However, some invasive plants may be "ecological traps" that attract birds but ultimately lead to a decrease in their survival or reproduction. Understanding these interactions may become increasingly important as birds and plants shift their ranges due to climate change.

We used case studies to examine the following questions:

- How do birds use invasive plants?
- Do invasive plants alter avian habitat selection or other activities?
- Are invasive plants "ecological traps" for bird communities?

Case Studies

Cape ivy (*Delairea odorata*)

This vine is native to South Africa and widespread as an invader in coastal California counties where it mostly invades shady riparian areas and forms monocultures that smother other vegetation. It is inedible to most wildlife species and may be toxic to aquatic organisms. While it does not produce seed in California, it can reproduce and spread easily from vegetative fragments.

Table 1

Potential changes in ecological processes induced by invasive plants – and how these changes may affect bird populations

Path	Ecological process	Potential effects on birds
Direct	Changes in physical vegetation structure: Density, height, phenology Nesting substrate & cover Foraging substrate & cover Insulation from weather	Changes in: Availability of nesting & foraging substrate Predation rates Food availability Insulation from weather Habitat selection dynamics
Direct & Indirect	Food web dynamics & components: Primary producers (i.e. displacement of native plants) Herbivores Detritivores Remainder of food web	Changes in: Food availability Habitat selection dynamics
Indirect	Physical processes: Hydrology Erosion/sedimentation, Fire & other disturbance processes Soil chemistry Nutrient cycling	Changes in: Availability of nesting & foraging substrate Predation rates Food availability Insulation from weather Habitat selection dynamics

A study in Marin County found that riparian birds rarely used Cape ivy for nesting (Gardali et al 2001). After Cape Ivy removal at Redwood Creek, the number of bird species, bird species diversity and overall species abundance all increased. In addition, three new species of nesting birds moved in: Swainson's thrush (*Catharus ustulatus*), Wilson's warbler (*Wilsonia pusilla*) and song sparrow (*Melospiza melodia*).

Perennial pepperweed (*Lepidium latifolium*)

Perennial pepperweed is native to Eurasia and invades throughout California in a range of habitats including agricultural areas, riparian corridors and marshes. In marshes, pepperweed changes the invertebrate community, particularly detritivores, thus altering the volume and characteristics of the organic matter that is used by other organisms (Whitcraft, unpubl data).

Several studies have examined birds in San Francisco Estuary marshes invaded by perennial pepperweed. Pepperweed displaces native plants such as bulrush (*Schoenoplectus* (= *Scirpus*) species) that are favored by California clapper rail and California blackrail, and in Suisun Bay clapper rails were never found in areas dominated by *Lepidium* (Estrella, unpubl. data). PRBO Conservation Science has extensive data on bird-vegetation relationships in marshes around the Bay (Spautz et al 2004). They found that perennial pepperweed used for nesting by songbirds when present and that its effect on song sparrow abundance varies by bay, with positive effects in central San Francisco Bay and Suisun Bay but negative effects in San Pablo Bay. Pepperweed showed a positive association with common yellowthroat presence (see also Herzog et al 2005) and with song sparrow territory density at the Suisun study site. There was no effect on song sparrow nesting success or California black rail abundance.

Giant reed (*Arundo donax*)

Giant reed is a tall (10m), fast-growing grass native to Eurasia that invades riparian areas throughout California, especially southern California. The impacts of giant include increased fire danger, reduced water flow and reduced shading of the water resulting in reduced habitat value for salmonids.

The Santa Ana Watershed Association found that after giant reed was removed from the Santa Ana River, endangered least Bell's vireos (*Vireo bellii pusillus*) pairs increased from 19 to 286 over 20 years, and continue to increase (Pike et al. unpubl). Seventy-six percent of vireos nested in native plants rather than in giant reed. Similarly, Kisner (2004) found that the number of nonlisted avian species declined by 32-41% as giant reed cover increased from 0 to 50%. Even a small coverage of giant reed caused negative impacts to the bird community.

French broom (*Genista monspessulana*) *and* Scotch broom (*Cytisus scoparius*)

These shrubs are native to Europe and create dense stands that outcompete other plants and increase fire danger, with seeds and foliage that are unpalatable to wildlife and seeds that can survive 20+ years in soil.

Bird distribution models for Golden Gate National Recreation Area and Pt. Reyes (Stralberg and Gardali 2007) showed that areas classified as broom dominant had fewer scrub-nesting focal species as well as fewer Bewick's wrens and common yellowthroats. Observations indicate that birds rarely use broom for nesting. The Marin Municipal Water District (Marin Co.) has found only one nest in broom during many years of intensive control efforts (J. Klein, pers. obs.) and PRBO researchers concur that nests are rarely found in broom (T. Gardali, pers. obs.).

Discussion

Interactions have been quantified for only a few species of birds and invasive plants. Most of these studies have been correlative, addressing bird abundance in association with invasive species cover; others are descriptive studies of birds returning to nest after invasives are removed. Few, if any, studies addressed the ecological mechanisms of these associations or were based on testing specific hypotheses using scientific methods. We found no data on the threshold of invasive plants that create negative impacts; most studies focus on areas of monocultures. While invasive plants may create habitat structure, they do not necessarily provide a good habitat for nesting or foraging. However, these hypotheses remain to be tested.

Management may be complicated by conflicting responses of different species or guilds of birds (or other wildlife) to invasive plants. Dense stands of some invasive plants, such as *Spartina alterniflora* hybrids (results not summarized here) do appear to be ecological traps. Revegetation with native species after removal of invasive plants can allow local bird populations to recover and therefore revegetation should be an integral component of invasive plant removal efforts.

Acknowledgements

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Timing of Application Influences the Efficacy of Glyphosate on Giant Reed (*Arundo donax*)

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We performed two experiments, in which glyphosate (1.5%) was applied on different dates. For container grown plants at Davis, application dates were September and October, November, 2006, April, June and August, 2007. In another experiment conducted near Fresno, CA, treatments were applied in September and October 2006 and June and August 2007. For container grown plants, leaf chlorophyll values declined the month following treatment and did not recover. The proportion of living stems displayed a similar response. By one year post treatment all treated plants appeared to be dead. For the larger Fresno plants, leaf chlorophyll values declined the month following treatment but recovered, except for plants treated in September, 2006. Plants treated in September had statistically significant lower values than untreated plants while plants treated in the other months did not. The proportion of living stems m^{-2} displayed similar results. Plants treated in September and October had the lowest proportion of living stems m^{-2} one-year after treatment. The lowest number of new stems produced in the growing seasons following treatment was for plants treated in September. These results suggest that late fall treatments (September and October) provide the greatest impact on giant reed.

Tulare County WMA Cost-Share for Invasive Weed Control

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Yellow starthistle proliferation is a serious threat to the biodiversity and the productive potential of California's rangelands. In 1985, over eight million acres were infested and by 1995 an estimated 12 million acres were infested. YST has continued to rapidly colonize susceptible habitats including 20,000 thousand acres in Tulare County foothill range. UC Cooperative Extension, the Tulare County Agricultural Commissioner, Tulare County RCD and the USDA NRCS formed the Tulare County Noxious Weed Task Force. This early organization led to official designation as a Weed Management Area (WMA). The WMA provides a structure to coordinate and collaborate in a local successful weed management effort, with key areas of research, education, outreach, inventory, control program and monitoring.

Research trials were conducted from 1997 to 2008 to determine best strategies for YST control in the Tulare County foothill range. Based on research trials, from 2002 thru 2005 Transline® was used in the control program; however based on continued trial results, from 2007 to the present, the control program has used Milestone® due to increased efficacy on several other invasive weeds that impact rangeland values, such as fiddleneck and Italian thistle.

In 2002, a rangeland YST cost-share control program was initiated with a three-year grant of $70,000. Grant funding has varied annually from a high of $46,000 in 2009 to zero funding in 2007. From 2002 to 2008, six out of seven years, the TCWMA has conducted a cost share program for YST control. During this period, 209 sites/properties were treated for a total of 1,219.5 acres. Eighty one percent of sites were treated once during this period; 16% and 10% were treated two and three times, respectively in the seven-year period. Sixty-six percent of the acreage was treated once and 15% and 13% treated two and three times respectively in the seven-year period. Direct cost per acre for WMA without grant or land owner match ranged from $117 per acre to $46 per acre with a six-year average of $60 per acre.

Active and Passive Restoration of Fountain Thistle (*Cirsium Fontinale* Var. *Fontinale*) Following Removal of Jubatagrass (*Cortaderia Jubata*)

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Abstract

Fountain thistle (*Cirsium fontinale* var. *fontinale*) is a federally and state endangered plant species endemic to the San Francisco Peninsula, with the majority of its populations occurring within the Peninsula Watershed of the San Francisco Public Utilities Commission (SFPUC). One of the populations has been heavily invaded by jubatagrass (*Cortaderia jubata*). As the result of a 12-year-long control program, the SFPUC has removed almost all of the jubatagrass, and this has permitted fountain thistle to begin to reclaim the lost habitat. A monitoring program is being conducted to track the progress of re-colonization of the habitat by fountain thistle. Initial surveys revealed an average rate of expansion of the fountain thistle population of 1.7 ft. (0.5 m) between 2007 and 2008 and of 2.6 ft. (0.8 m) between 2008 and 2009, or an average rate of about 2.2 ft. (0.7 m) per year. At this relatively slow rate of spread, there is the risk of re-inva-

sion of cleared habitat by invasive plants. Tall fescue (*Festuca arundinacea*) is rapidly increasing at the site and threatens to exclude fountain thistle from its potential habitat. Therefore a program of active restoration, involving the planting of California hairgrass (*Deschampsia cespitosa*), the most common native associate of fountain thistle in the Watershed, was begun in 2009 to supplement revegetation through passive recruitment and to provide a matrix of native plants that would resist further invasion. Survivorship of hairgrass will be followed to determine the effectiveness of this approach.

Introduction

The fountain thistle (*Cirsium fontinale* var. *fontinale*) is a federally endangered species that grows only on the San Francisco Peninsula, with most of the plants growing within the Peninsula Watershed of the San Francisco Public Utilities Commissiion (SFPUC). It is restricted to a unique serpentine seep and wetland habitat. One of the populations had been largely displaced from its habitat by the invasion of jubatagrass (*Cortaderia jubata*). Invasion of the habitat by jubatagrass has been identified as one of the principal threats to fountain thistle by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1998).

Over the past twelve years the SFPUC has progressively removed the jubatagrass, opening the habitat to fountain thistle re-colonization (Thomas and Ciardi 2008). The SFPUC is now attempting to restore the fountain thistle habitat. To accomplish this, it is pursuing two basic approaches to habitat restoration, passive restoration and active restoration. Passive restoration is the reliance mostly upon natural ecological successional processes, with minimal human interference, to direct the course of restoration. Active restoration employs human intervention to accelerate natural processes or to achieve a desired outcome.

Passive Restoration – Methods and Results

Following jubatagrass removal, the SFPUC followed the passive approach to restoration, employing natural succession and seedling recruitment to re-establish fountain thistle plants and the serpentine seep plant community. It was found that new fountain thistle plants were able to establish around the old dead bases of the jubatagrass.

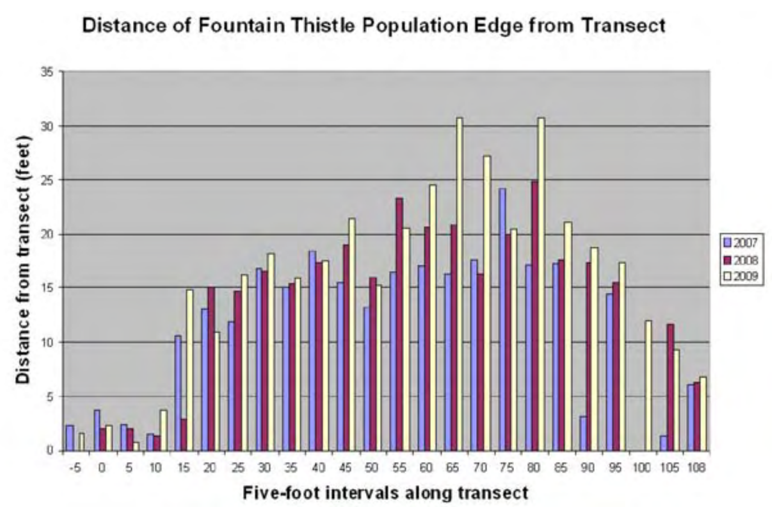
To determine the rate of expansion of fountain thistle into the cleared habitat through passive recruitment, an ongoing annual survey is being conducted of the fountain thistle population. This involves the measuring of the distance to the edge of the population at intervals along a permanent transect. The distance to the edge of the population is determined by extending perpendicular transects every five feet along the permanent transect to the farthest fountain thistle (the population edge).

The results of the population monitoring are shown the bar chart in Figure 1. This shows the distances measured from the permanent transect to the population edge in 2007, 2008 and 2009. It was found that the margin of the population had a net expansion of 1.7 ft. between 2007 and 2008 and of 2.6 ft. between 2008 and 2009 or an average rate of expansion of 2.2 ft.

As shown in Figure 1, the population margin did not expand uniformly along the length of the transect from year to year and in some locations showed year-to-year contractions. This is because fountain thistle is a short-lived perennial and population expansion depends upon the vagaries of seed dispersal and seedling recruitment. However, the overall effect of passive recruitment was

Figure 1

Expanion of fountain thistle population between 2007 and 2009 into cleared habitat, as indicated by distance to population edge from transect at 5-foot intervals along transect.



net growth of the size of the population.

Active Restoration – Methods and Results

Because the expansion of the fountain thistle population through passive recruitment is relatively slow, its habitat has been subject to re-invasion by jubatagrass and other non-native plants. To determine the extent of colonization by non-native invasive plants, compared with that by native plants, we conducted a survey for per cent plant cover in the cleared habitat, using the point intercept method and stratified random sampling. Parallel transects were placed through the open habitat feet apart, and point intercepts were obtained at randomly selected distances along them.

The results of this sampling are shown in Figure 2. While the greatest cover was found to be for a native plant, seep monkeyflower, the aggregate cover of non-native plants was found to be greater than that for native plants. One of these non-native plants, tall fescue, is increasing rapidly at the site and appears to be replacing jubatagrass as the most significant invasive plant.

Plant Species or Land Cover	Per Cent Cover
Dead remains of jubatagrass (Cortaderia jubata)	46.9
Seep monkeyflower (Mimulus guttatus)	16.4
Bare ground	15.5
Rabbit's foot grass (Polypogon monspeliensis)	12.6
Tall fescue (Festuca arundinacea)	2.4
Iris-leaved rush (Juncus xiphiodes)	1.4
Sow thistle (Sonchus oleraceus)	1
Live jubatagrass (Cortaderia jubata)	1
Fountain thistle (Cirsium fontinale)	1

Figure 2

Cover values for fountain thistle habitat, determined by point incecept method, showing significant colonizationby non-native plants.

Because of the threat of re-invasion by non-native plants, an active revegetation program was begun in 2009. This involves the planting of a native bunchgrass, tufted hairgrass (*Deschampsia cespitosa*), the most common associate of fountain thistle in most of its habitat. Tufted hairgrass seeds were collected in the Watershed from plants growing in nearby fountain thistle populations. These seeds were given to the San Bruno Garden Project, a non-profit organization involved in environmental education, to use for growing plugs of tufted harigrass in their native plant nursery.

Two hundred plugs of tufted hairgrass were planted at the fountain thistle site with the assistance of Garden Project Earth Stewards. These were identified with numbered metal tags secured in place with galvanized nails. Survivorship of hairgrass will be monitored to assess the effectiveness of this approach.

Discussion

There has recently been debate among practitioners about the relative merits of passive and active restoration, for example in management of parks (U.S. National Park Service 2005). Though it has traditionally been thought that it is better to rely upon natural processes, anthropic disturbances to the environment, such as the introduction of invasive species, have been so great that some human manipulation may be necessary.

Though fountain thistle is reclaiming its habitat through natural recruitment, this process is relatively slow. With a net population expansion rate of less than two feet per year, it will take many years for it to re-occupy the space vacated by removal of jubatagrass. In the interim, this potential habitat will be taken over by non-native plants that may competitively exclude it.

In the study of ecological succession, plants are placed along a gradient from those termed 'r-selected' to those termed 'k-selected'. R-selected species are those with life history traits that maximize reproduction, leading to rapid population growth rate. K-selected species are those that maximize the growth and survival of individual plants, leading to success under more crowded or competitive conditions (Cotgreave and Forseth 2002).

The slow rate of re-colonization by fountain thistle is explained by the fact that it is a k-selected species. It produces a small number of achenes with dehiscent pappus that are dispersed close to the parent plants (Powell 2007). Powell found that fountain thistle produces an average of only 356 seeds per plant. It also has an obligate out-crossing breeding system.

Fountain thistle also has relatively large achenes for a thistle. My measurements of seed weight for filled seeds assumed to be viable gave an average seed weight of 8 mg. A seed sample in the seed bank at the Rancho Santa Ana Botanic Garden had a lower seed weight (4 mg.), but seed germination rate was only 57 percent, and it was concluded that many of the seeds may have only been partially filled. The same characteristic of large seeds dispersed close to parent plants has been found for fountain thistle's conspecific relatives, the Mount Hamilton thistle (*C. fontinale* var. *campylon*) (Hillman 2007) and the Chorro Creek bog thistle (*C. fontinale* var. *obispoense*) (Chipping 1994).

In contrast, the non-native congeneric bull thistle (*C. vulgare*) is an r-selected species and an aggressive colonizer. It has a large number of lighter seeds dispersed farther from parent plants. Its seed weight ranges from 2 to 4 mg. (Halevy 1989). Powell found that bull thistle produces as many as 16,969 seeds per plant and that it has an autogamous (self-pollinating) breeding system.

This difference in colonizing ability can be understood in terms of the difference in adaptive strategies between k-selected and r-selected species. Fountain thistle occupies a narrow band of serpentine wetland habitat surrounded by unfavorable dry serpentine habitat. Seeds dispersed far from the parent plants would be wasted because seedlings would fail to survive. Bull thistle typically grows in disturbed habitat which is best colonized by small widely dispersed seeds.

It may be concluded that passive restoration is appropriate for early successional species and colonizing species, such as seep monkeyflower and bull thistle. With rare and endangered k-selected species, such as fountain thistle, species recovery may be best achieved through a program that includes active restoration rather than one solely relying on passive restoration.

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Weed Control and Habitat Restoration in Saline Habitat

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Vegetation management is often just hard work: control weeds, amend soils, plant natives, maintain things during establishment and maybe some long-term maintenance to ensure the community stabilizes as intended. However in habitats adjacent to San Francisco Bay basic tactics have not met with success, forcing managers to reconsider dominant paradigms and test novel tactics. For three years we have attempted to establish grasses in an effort to preclude invasive forbs during habitat creation as recommended in the site's management plan, but have found grasses difficult to establish onsite and ineffectual against invasive forbs. Further background research and the casual introduction of native forbs led us to reconsider the grassland focus, so we will be testing native forbs this fall. Another novel tactic is the use of saltwater as an herbicide against intolerant weeds. It is relatively inexpensive, in saline habitats it can be applied heavy enough to hold ground against intolerant weeds longer than any herbicide and the treatment is essentially supplemental irrigation for native halophytes.

Planting the Seed: Student Participation in Habitat Enhancement

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Upper Newport Bay has benefited from hands-on restoration work performed by students from Early College High School (ECHS). A unique partnership with ECHS has proven an excellent tool for improving the health of natural communities while increasing environmental awareness and community participation through practical education of high school students. Students participate in four field sessions over the course of a school year. They learn to recognize a variety of invasive plants in local wild spaces, soon realizing that many of these plants exist in their own backyards. Over the course of the year, they remove exotic species, install native plants and seed and maintain their plantings, all while observing the subtle changes of southern California's seasons reflected in their adopted restoration site. The successes and challenges of this program have yielded many programmatic lessons over a three-year partnership between the California Coastal Commission, Orange County Parks and ECHS. Follow a simple "toolkit" highlighting methods for creating similar programs with high schools to increase habitat awareness in students and reap rewards for your site!

Student Paper Contest

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

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Abstract

Several populations of a non-native salt tolerant plant, *Limonium ramosissimum* (Algerian sea lavender), were discovered in South San Francisco Bay marshes in 2007, but whether the plant can disperse to similar habitat and how the estuary's salinity gradient will affect spread is unknown. To determine this, we mapped and surveyed populations to characterize the habitat it invades, floated seeds at different salinities in aquaria to test dispersal potential and in a tidal simulator grew *L. ramosissimum* from seed to flowering under crossed inundation and salinity treatments testing potential for an estuary-wide invasion. Mapping and survey results indicate *L. ramosissimum* invades disturbed and restored marshes and is located near similar habitat. In the aquaria study, 50% of seeds remained floating after four days in saline water and, after two weeks in saline water, 90% of seeds germinated when exposed to fresh water, indicating high biological dispersal potential. Plants grown under crossed inundation and salinity treatments grew significantly faster and produced more seed when exposed to fresher and drier conditions, indicating plants will grow more rapidly in the high marsh and further up-estuary where salinities are lower. *L. ramosissimum*'s potential to spread throughout the estuary and in restoration sites warrants removal.

Introduction

Invasive plants threaten San Francisco Bay's restored and remaining salt marsh plant communities making early assessments of the potential for non-native species to spread essential. In 2007, two sub-species of Algerian sea lavender (*Limonium ramosissimum* ssp *provinciale* and *L. ramosissimum*; Figure 1) were observed in San Francisco Bay salt marshes. Both subspecies have invaded marshes and tidal lagoons in southern California (Page et al, 2007).

Prior invasion history is a key predictor of future invasions (Kolar and Lodge, 2001), but whether the conditions required for a wide-spread invasion: access to an invasible landscape, the ability to deliver propagule pressure and the species' tolerance to conditions in the new environment (Lonsdale, 1999) in San Francisco Bay marshes, is unknown. To address this, we have mapped and surveyed *L. ramosissimum* ssp. *provinciale* populations in S.F. bay marshes to determine the habitat the plant invades, tested dispersal potential in an aquaria study and investigated how inundation and salinity, key factors controlling salt marsh plant distributions (Bertness et al, 1987), will affect invasion rates across the estuary's salinity gradient.

Methods

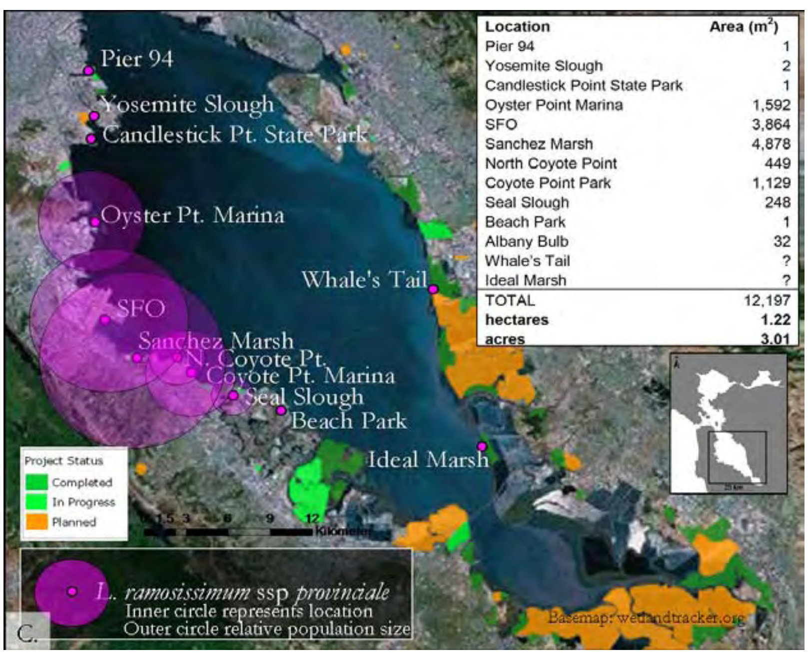
To find and map *L. ramosissimum* ssp. *provinciale* populations, based on initial population locations we visually searched marshes and shoreline on the west side San Francisco Bay from Muzzi Marsh, Corte Madera to Beach Park, Foster City in 2007-08 using Google Earth. Invasive Spartina Project staff reported populations on the east and west side of the Bay. Once identified, populations were mapped using a Timble GeoXH GPS and percent cover estimated at the patch scale.

L. ramosissimum *L. ramosissimum* ssp. *provinciale*

Populations at Sanchez Marsh, Seal Slough and Coyote Pt. Marina were surveyed with a laser level and RTK GPS to determine the elevation range ssp. *provinciale* has established. Restoration status of invaded habitats and location relative to additional marsh habitat was determined using wetlandtracker.org.

To test dispersal potential we simulated estuary wide seed dispersal followed by a rain event. Seeds were collected at Sanchez Marsh, Burlingame in October 2007 and floated in replicated (n=5) 0, 15 ppt and 30 ppt salinity water in aquaria tanks. Length of time seeds floated was recorded and after 0, 1, 2, 4, 7 and 14 days, 15 seeds were removed from each treatment and germinated in petri dishes in fresh water.

To test how key abiotic factors will effect invasion rates along the estuary's salinity gradient, seeds were germinated in a greenhouse experiment in pots in fresh water and then grown for six months under replicated (n=7) crossed salinity-inundation treatments in a tidal simulator. Plants were inundated for two hours daily, twice a week, or twice a month with 0, 15 ppt, or 30 ppt salinity water. Growth metrics and flower production were measured.



Results/Conclusions

Marsh and shoreline searches have identified 13 discrete populations of *L. ramosissimum* ssp. *provinciale* which cover a combined 3.01 acres of marsh (Figure 2) and one population of *L. ramosissimum* at Strawberry Marsh in Mill Valley. Populations of *L. r*. ssp. *provinciale* range in size from 3864 m^2 at Sanchez Marsh, the geographically central and largest population, to less than 1m^2 at marshes at the northern and southern edges of the invasion range, indicating the population is spreading from a central location. Average percent cover of patches per site is correlated with the total area invaded per site (R2 = 0.78), indicating as populations grow in area they become increasingly dense, evidence of an intensifying invasion.

Mapping results show invasions are predominantly located in disturbed and restored marshes: three at completed restoration projects, two at in-progress restoration projects, two at planned restoration projects, four at disturbed marshes (ie. marinas) and two on beaches. At Sanchez Marsh, where the largest population is located, more than 50% of an area restored to tidal marsh habitat in 1987 is now dominated by *L. r.* ssp. *provinciale*. These populations are also located near to large completed, ongoing and future salt marsh restoration projects, including some of the largest tidal wetland restoration projects in the Bay (ie. Bair Island Restoration Project, 1385 acres and South Bay Salt Pond Restoration project, 13,500 acres) indicating extensive invasible habitat is available for spread.

Survey results at Sanchez Marsh, Coyote Pt. Marina and Seal Slough indicate *L. r.* ssp. *provinciale* establishes from the upper edge of the low marsh (MHW, approx 1.7 m above mean sea level) through the upper edge of the high marsh (MHHW, approx 2.4 m) and receives corresponding large differences in tidal inundation frequency, from daily to approximately bi-monthly. *L. ramosissimum* spp. *provinciale* growth and reproductive output is correlated with days of inundation per year (R2 = 0.45) and plants higher in the intertidal produce more flowers and seed.

Results of the aquaria dispersal study demonstrate seeds can float in bay water then germinate, but that dispersal distance will vary with the salinity of water in which seeds float. After four days floating in 15 and 30 salinity water, 78% of seeds remained afloat compared to only 32% of seeds in 0 salinity water. Seeds in zero salinity germinated in aquaria beginning day 4, effectively ending dispersal potential. 25% of seeds in 15 and 30 salinity water were still afloat when the float test was ended, after 14 days. Seeds that were removed from aquaria and germinated in fresh water, regardless of salinity and duration seeds floated, had no significant difference in viability and on average 86.7% of seeds germinated 16 days after removal from aquaria treatments. These results indicate seeds are biologically capable of long dispersal distances in bay water at brackish and oceanic salinities.

When plants establish in a new location, how they respond to local abiotic conditions will influence their invasion rate. Survey data indicated *L. r.* ssp. *provenciale* growth and reproductive rates are sensitive to inundation frequency, but because salinity and moisture co-vary with inundation in the marshes we surveyed (R2 = 0.45), it was unclear which factor, inundation and/or salinity, was driving the morphological variation observed. Results of our tidal simulator crossing these factors indicate *L. r.* ssp *provinciale* growth is influenced by both inundation and salinity and that these factors act independently (Figure 3). Plants grows faster and produce more inflorescences when either salinity or inundation stress is relaxed. These findings suggest invasion rates are likely to be higher in fresher marshes than salty marshes.

Combined, these studies suggest *L. r.* ssp. *provinciale* has the potential for widespread invasion in San Francisco Bay salt marshes. The plant has a history of invading restored and disturbed marshes and is proximate to additional habitat. Seeds are biologically capable of long distance dispersal and invasion rates, should populations establish in the lower salinity marshes, are likely to accelerate. While research into the impacts of how *L. ramosissimum* affects salt marsh biota and its ability to spread in undisturbed marshes are important additional research questions, we recommend based on *L. ramosissimum*'s potential for invasion that land managers prioritize the eradication of this non-native wetland species.

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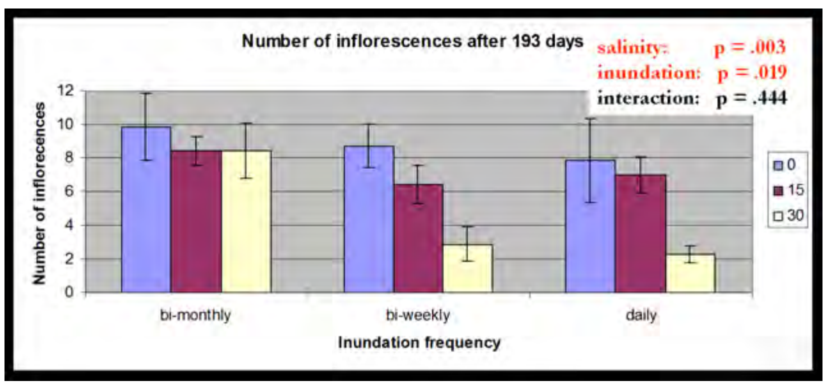

Experimental Test of Different Treatments for Control of Terracina Spurge (*Euphorbia terracina*): Comparison of Hand Pulling, Glyphosate, and Chlorsulfuron

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Abstract

Terracina spurge (*Euphorbia terracina*) has become a major invasive plant pest threatening wildlands in coastal southern California. This species is highly invasive in Australia but in the United States it is found only in the coastal regions of Los Angeles County and in Pennsyl-

vania. This species has been spreading rapidly over the past five years in the Los Angeles area and has demonstrated an ability to invade a wide variety of habitats and microclimates. We tested combinations of three different treatments for control of this species (glyphosate, chlorsulfuron and hand pulling). We also investigated the need to hand pull individual weeds around regrowing native vegetation.

Our experiment was initiated as part of a post-fire revegetation project in Solstice Canyon, a site within the Santa Monica Mountains National Recreation Area. The experiment included six treatments: hand pulling in the plot with and without hand pulling around individual native plants; spot spraying of 2% glyphosate with and without hand pulling around native plants; and spot spraying of chlorsulfuron at 15g/hectare with and without hand pulling around native plants. We did not include a control treatment because we are trying to eliminate this species at the site, however, we did take observational data on Euphorbia performance at an adjacent site where it is not being controlled. This data allowed us to evaluate yearly fluctuations in Euphorbia performance independent of our treatments. Initial results indicated that there was a marginally significant difference in Euphorbia cover among treatments. Chlorsulfuron was the most effective treatment (63% decrease in Euphorbia cover) followed by chlorsulfuron with hand pulling (52% decrease). Hand pulling leaving *E. terracina* around natives was ineffective (30% increase in Euphorbia cover overall). We are continuing the treatments for another two years to examine long-term effects of herbicide and hand pulling on the seed bank, native plant regeneration post-fire, and native plant response.

Introduction

In the past four years in excess of $600,000 and over 2600 hours have been spent on eradication of the highly noxious invader Terracina spurge (*Euphorbia terracina*) on NPS lands. Control efforts have been a combination of glyphosate spraying and hand pulling. Given the invasive character of the invader we anticipate long term management efforts will be necessary, therefore selecting the most efficient means of control is crucial. The aim of this project is to ensure that we are using the most effective approach by comparing the efficacy of six different treatments: a post-emergent herbicide, a pre- /post- emergent herbicide and hand pulling. The purpose of this research is 1) to determine if costly hand pulling around natives is needed to ensure native survival, 2) to ascertain which treatment is most effective at controlling target invasives and promoting native establishment and 3) to explore the potential impacts of these herbicides on native germination and growth.

The herbicides used in this experiment were chosen based on previous NPS experiments and published literature. Although we have used glyphosate in the past to treat Euphorbia and have found it to be effective, published literature from Australia suggested that chlorsulfuron might be even more effective for long-term control (EWAN 2000). Therefore long term monitoring of the plots for three years following first treatment will be done to measure its effects on Euphorbia and native seed germination.

Methods

We conducted our study in Solstice Canyon, a site within the Santa Monica Mountains National Recreation Area. A total of eight sites were chosen based on the mix of native species and Euphorbia to simulate field conditions experienced when managing wildlands within this region. Sites were set up in 2008 and treated yearly and monitored biannually: once pre-treatment and once six months post-treatment. In 2009, we also collected post-treatment data one month later to observe short-term effects. Observations of the long-term effects of herbicide and hand pulling on both the seed bank and native plant regeneration post-fire will be continued until 2010.

Experimental design

The sites were prepared in May 2008. Each site was divided into six fixed 2m^2 plots with one meter borders on each side. These borders were installed to avoid cross contamination between each treatment and from outside the treatment site. In the center of the $2m^2$ plot a $1m^2$ area was permanently set up to be used for data collection. These plots were randomly assigned to one of six treatments: glyphosate + no pull, glyphosate + pull, chlorsulfuron + no pull, chlorsulfuron + pull, pull + no pull, and pull + pull. The assignment of treatment determined whether the plot would be sprayed with a 2% solution of glyphosate (post-emergent herbicide), sprayed with chlosulfuron (pre-/post-emergent herbicide) at 15g/hectare, or if hand pulling was necessary. Pull specified that all target weeds were to be pulled within a 10 cm. proximity to natives. No pull indicated that no such pulling would occur. This was consistent for all assigned treatments except for pull + pull and the pull + no pull treatments. In the pull + pull treatment every target weed was pulled regardless of proximity to natives. In contrast, the pull + no pull treatments pulled every target weed except those within 10 cm. of natives. Weeds and the ground (to test the pre-emergent effect on seedling germination) were sprayed. Care was taken not to spray any natives in the treatment areas.

Data collection

In June of 2008 the first of the three yearly treatment applications was conducted. Prior to performing each assigned treatment the $1m^2$ data collection area was assessed for percent cover (estimation of the total area occupied) of Euphorbia, native vegetation, non-native vegetation and bare ground. Native plant heights were also recorded. The same data was collected in post-assessments. To examine the effectiveness of treatment, percent cover of dead weeds and resprouts were also collected at this time. Photographs were taken at time of data collection pre- and post- treatment to visually monitor treatment effect. To evaluate natural yearly fluctuations in Euphorbia performance assessment data was collected from an adjacent property where Euphorbia control measures have not been attempted.

Data Analysis

ANOVA analyses were used to determine if there was a change in percent cover from 2008 to 2009 across treatments. Paired two-tailed t-tests were performed to determine if there were percent cover changes within treatments. Native percent cover among treatments was not normally distributed therefore a non-parametric ANOVA analysis was applied. Lastly, percent reduction and/or increase were calculated for all data collected.

Results

Comparing percent cover across treatments we found there was a marginally significant difference between treatment effectiveness on percent cover of Euphorbia ($F = 2.129$, $P = 0.081$; Figure 1). There was no significant difference in treatment effect on native percent cover ($K = 1.716$, $P = 0.887$; Figure 2). There was no significant difference in treatment effect on non-native percent cover ($F = 0.313$, $P = 0.90$). Comparing percent cover within treatments from 2008 to 2009 revealed that the glyphosate ($P = 0.004$), chlorsulfuron ($P = 0.038$), and chlorsulfuron + pull ($P = 0.003$) treatments significantly reduced the percent cover of Euphorbia (40%, 63%, and 52% respectively). Non-native cover significantly increased (≥ 48%) in all plots. Total time spent performing treatments in 2008 was seven hours on all spray treatment types and 26 hours for the pulling treatments. In 2009 time spent for all spray treatment types was eight hours and for the pulling treatments was 21.5 hours.

Discussion

Telar was significantly better than the pull treatment at controlling Euphorbia. Pairwise comparisons showed that the only two treatments that significantly differed in resulting Euphorbia cover was the pull + no pull treatment and the chlorsulfuron treatment ($P = 0.047$). Glyphosate, chlorsulfuron, and chlorsulfuron + pull significantly reduced Euphorbia coverage.

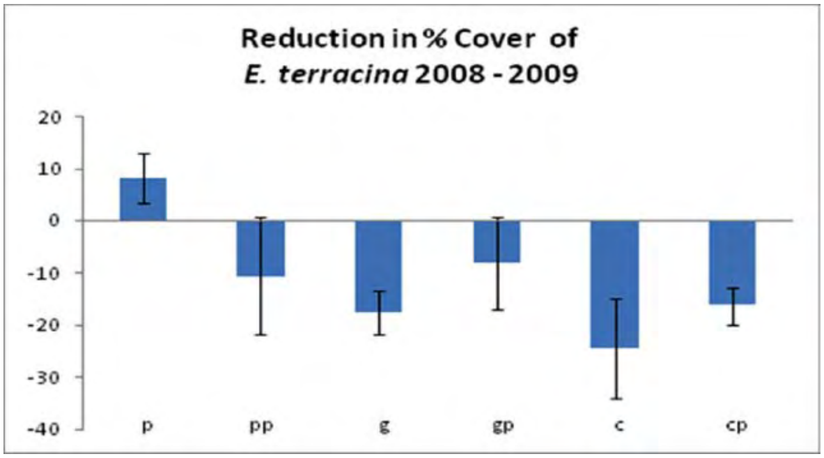

Figure 1

Graph showing percent cover difference in E. terracina from 2008 to 2009. The following defines what each treatment stands for: p = pull + no pull, pp = pull + pull, g = glyphosate + no pull, gp = glyphosate + pull, c = chlorsulfuron + no pull, and cp = chlorsulfuron pull. (Mean ± SE, n = 8).

We are confident that these results reflect treatment effects rather than natural fluctuations in Euphorbia performance because monitoring of the uncontrolled site showed a greater density of Euphorbia than was recorded at the treated sites (Figure 3). Reduction in Euphorbia was more effective in herbicide treatments that were not coupled with pulling. It appears that over the short term pulling does not augment Euphorbia control. Long term monitoring may continue this trend but it could also show that pulling may increase native establishment and performance or more rapidly deplete the seed bank. This was reflected in our native height data.

We found that all treatments had a positive effect on native performance. Tracking growth of natives from 2008 through 2009 showed that native growth was greater in treatments that were coupled with pulling. The herbicide + pull treatments had twice as many sites with an increase in native plant height compared to the herbicide without pulling treatments. At the conclusion of this project we will be able to determine if our current methods are the most effective at controlling Euphorbia and promoting native growth. This information in turn will be used in managing wildlands parkwide.

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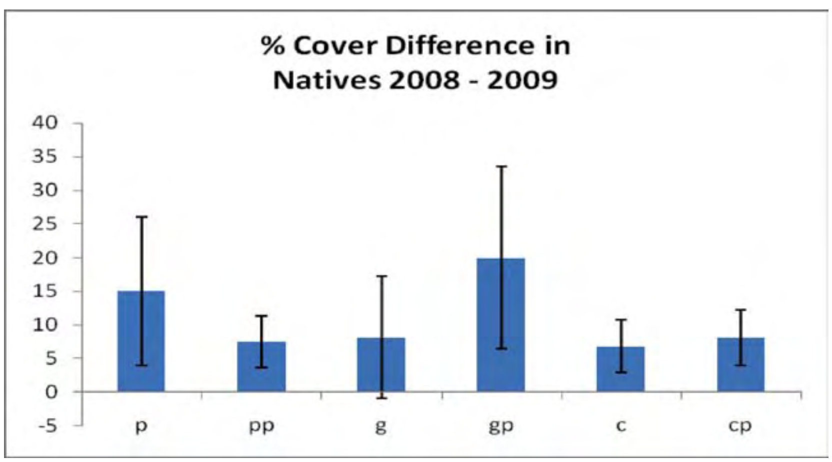

Figure 2

Graph showing percent cover difference in natives from 2008 to 2009. The following defines what each treatment stands for: p = pull + no pull, pp = pull + pull, g = glyphosate + no pull, gp = glyphosate + pull, c = chlorsulfuron + no pull, and cp = chlorsulfuron + pull. (Mean ± SE, n = 8).

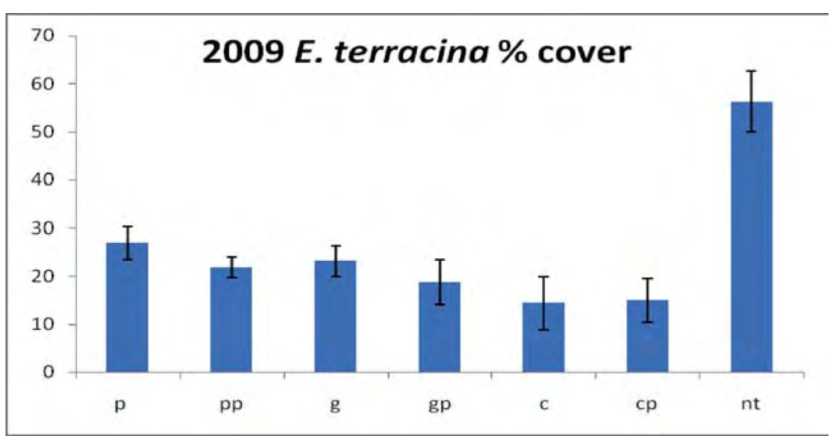

Figure 3

Graph showing percent cover of E. terracina in 2009. Data is pooled for each treatment type. The following defines what each treatment stands for: p = pull + no pull, pp = pull + pull, g = glyphosate + no pull, gp = glyphosate + pull, c = chlorsulfuron + no pull, and cp = chlorsulfuron + pull, nt = no treatment. (Mean ± SE, n = 8).

Non-native Grass and Forb Control in a California Grassland

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Abstract

California grasslands have been invaded by a suite of Mediterranean annual grasses for over 200 years. The conversion from a native bunchgrass and annual forb grassland to non-native, annual grassland has negative impacts on native soils, vegetation and wildlife. These non-native grasses can limit germination and establishment of native species by shading seeds, altering water availability and overcrowding seedlings. Prescribed burning of invaded grasslands is a common method of non-native plant control. Following prescribed fires, non-native forbs may increase in cover in the absence of non-native grasses. The objectives of this study were to assess the effectiveness of prescribed fire in reducing non-native grasses and weeding of non-native forbs in releasing native plant species from competition. Following a wildfire in 2006, three treatments were established within and adjacent to the burn area: burn only (BO), burn + weeding (BW) and unburned (UB). Plant species percent cover was recorded annually for three years. Exotic cover was significantly reduced by fire. Both burn treatments increased native forb richness, but only BW treatments increased native grass and forb cover and richness. Our results suggest that prescribed burns effectively reduce non-native grasses and may increase native richness; however, native cover and richness can be increased further with follow-up control of non-native forb species.

Introduction

Non-native annual grasses are often the focus of non-native plant management in California grasslands. This focus has multiple justifications as non-native grasses have been found to reduce native plant cover and richness and alter soil chemistry and microbial communities (Eliason & Allen 1997; Ehrenfeld 2003); but, also because there are effective means by which to do so. Prescribed burns have been successful at reducing non-native annual grass cover by reducing annual grass seed input (Moyes et al.2005). Most annual grasses invading California grasslands do not have a long seed-bank life; removal of one year's input can significantly reduce non-native annual grass cover for the following couple of years (D'Antonio 2007).

In addition to non-native grasses, native plant species may be competing with non-native forb species. In a matrix of non-native grass and non-native forbs, it has been found that non-native forbs may facilitate native forb species. When non-native grasses are removed from the matrix, the relationship between non-native forbs and native plant species may shift to competition (Gillespie & Allen 2004).

Following prescribed burns, non-native forbs become the dominant plant functional group. Control of non-native forbs, such as *Erodium* spp., following fire is not common practice and research concerning the effectiveness of such control is lacking. Non-native forbs introduce complications to management that grasses do not. The majority of natives in California grasslands is forbs and thus would be susceptible to the same herbicides as non-native forbs. The use of fire to reduce non-native forbs would require burning to occur while native forbs are actively growing or in flower thus risking loss of native seed input. The objectives of this study were to determine 1.) if fire reduces non-native annual grass and increases native plant species cover and 2.) if hand removal of non-native forbs following fire further releases native species from competition. Since the presence of non-native grass reduces native diversity and cover; and, non-native forbs may also reduce natives in the absence of non-native grasses, we hypothesized that fire would reduce non-native grass and increase native cover and weeding would further increase native cover and richness.

Methods

Santa Rosa Plateau Ecological Reserve is located in southwestern Murrieta, Riverside County, California (33o31o N, 117o15’ W, 600m a.s.l.). The reserve consists of 8,200 acres and five distinct habitats, including grasslands. Soils are mainly basalt in origin. The climate is Mediterranean with cool, moist winters and hot, dry summers. Average annual precipitation is approximately 48cm with the majority falling between November and April.

Following a summer wildfire in 2006, nine burned plots were established in the burn area (BO) and nine unburned plots (UB) were established in the unburned area. An additional nine weeding plots (BW) were paired to BO plots just before the first rains of the 2006-07 season. Weeded plots were hand weeded throughout the season ending three weeks before sampling was conducted. Plant percent cover and richness were recorded during peak growth. Data were analyzed within years to test for differences in plant species cover and richness across treatments. Due to non-transformable data in 2006 and 2007, Kruskal Wallis analysis was utilized. For 2008 and 2009 non-normal data were transformed using Log +1 or square root and analyzed using ANOVA.

Results

Non-native richness was highest in UB treatments in 2006; however, BO treatments reached similar non-native richness by 2007 (table 1; fig. 1). BW treatment had lowest non-native richness because non-natives were removed. Native richness was lowest in UB treatment except in 2006 when the burn had removed all species from burned treatments. BO and BW were similar and highest in 2007, but over time BO became more similar to UB and native richness remained highest in BW (Table 1; Figure1).

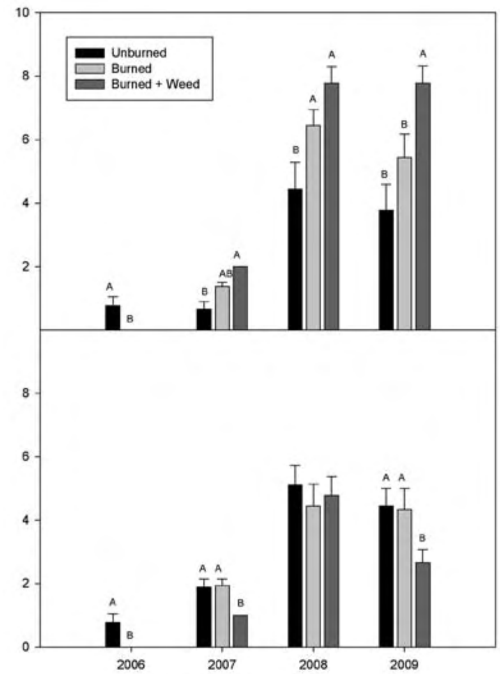

Figure 1

Native and non-native richness per 1x.5m^2 recorded summer of 2006 and peak season 2007-2008. Connecting letters are from within year comparisons

Non-native grass cover was highest in UB plots for all years after fire. BO and BW treatments had similar cover after fire until BO treatments became similar to UB in 2008 (table 1; Figure.2). Non-native forb cover was lowest in UB treatments after fire while BO and BW were similar. By 2008 UB and BO became similar and in 2009 BO had the highest non-native forb cover (Table 1; Figure. 2).

Native grass cover was highest in the BW treatments in 2009 and did not differ in any other years. Native grass cover did not reach UB cover levels in BO treatment three years post-burn. Native forb cover was highest in the BW treatments in 2008 and 09, while BO and UB did not differ (Table 1; Figure.3).

Table 1

Chi-Square and P values for richness and cover for 2006 and 2007 analyzed within year using Kruskal Wallis due to non-transformable data. F ratios and P values for richness and cover for 2008 and 2009 analyzed within year using ANOVA. * Indicates non-native forb cover was analyzed with Kruskal Wallis and thus the statistic reported is X^2.

	2006		2007		2008		2009	
	X^2	P-value	X^2	P-value	F-value	P-value	F-value	P-value
Non-native richness	6.429	0.011	12.384	0.002	0.277	0.761	3.235	0.057
Native richness	8.196	0.004	9.484	0.009	6.909	0.004	8.124	0.002
Non-native grass	1.000	0.317	21.751	<.0001	25.474	<.0001	36.995	<.0001
Non-native forb	3.375	0.066	11.749	0.003	10.492	0.001	*14.6131	0.001
Native grass	3.367	0.067	1.119	0.571	2.551	0.099	2.829	0.079
Native forb	4.763	0.029	3.135	0.209	11.295	0.000	11.504	0.000

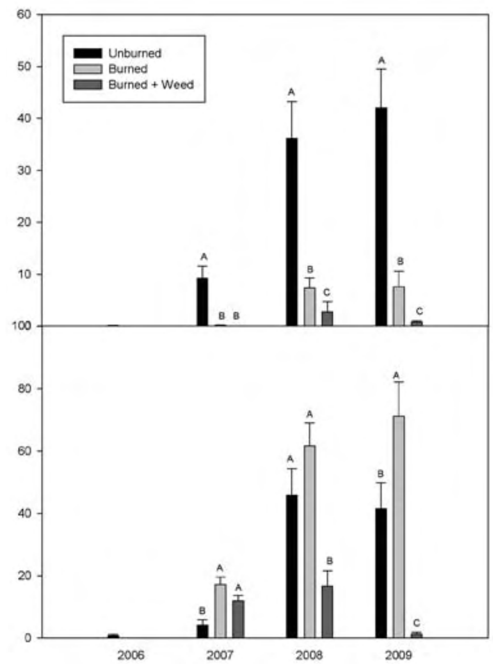

Figure 2

Non-native grass and forb cover per 1x.5m^2 recorded summer of 2006 and peak season 2007-7008. Connecting letters are from within year comparisons.

Discussion

Fires occurring while non-native annual grass seed remains on standing biomass reduces seed input to levels that significantly lowers non-native grass cover the following season. In our study, non-native grass cover remained low for 2-3 years before beginning to increase towards pre-burn cover. These results are consistent with the four year recovery period found by D'Antonio (2007). Removal of non-native grasses by fire alone did increase native species richness initially, but total native cover did not significantly increase. Within two years of the burn, this increased richness faded as non-native grass began to reinvade. Therefore, once a grassland has been burned, continued management efforts will be necessary to prevent reinvasion and dominance of non-native grasses; and, further management is necessary to increase native plant cover.

Many non-native forbs have received little attention in terms of control in grasslands. Yet, post fire, non-natives such as *Erodium* spp. can become dominant and limit native species recovery. While non-native forbs such as Erodium may act to aid natives in mixture with non-native grasses, this project demonstrates that when non-native grasses are reduced, non-native forbs can prevent native recruitment and recovery. Removal of non-native forbs allowed for high cover of native forbs and grasses. Native grasses, which in this study was composed mainly of *Nassella pulchra*, did not recover as well in BO plots as in BW plots and was lower in BO plots than UB plots (Figure 3). This suggests that non-native forbs are competing with *Nassella pulchra* and reducing *N. pulchr*a recovery after fire. To ensure that native forb and grass richness and cover increase after burns, non-native forb control will be necessary. Weeding of non-natives, while helpful in testing non-native forb effects on native species, is not realistic at the reserve level. Further research testing alternative control methods such as carefully timed herbicide applications are necessary.

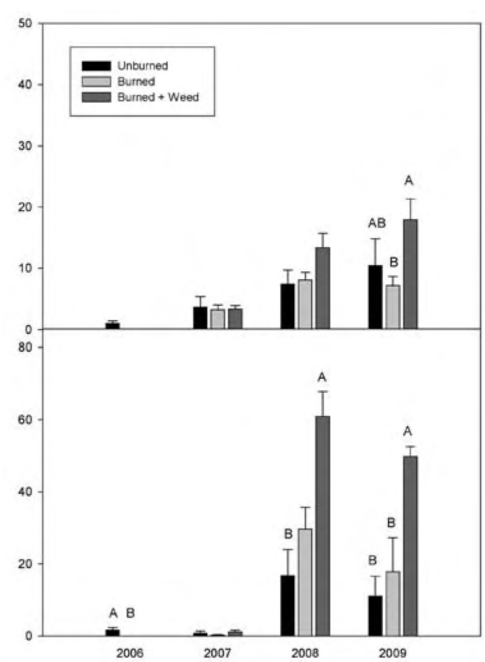

Figure 3

Native grass and forb percent cover per 1x.5m^2 recorded summer of 2006 and peak season 2007-2008. Connecting letters are from within year comparisons.

We further demonstrated that it may take two or more years of repeated forb control following fire before natives increase. This may be due to environmental conditions following fire such as precipitation or may be a delayed response in germination. California grassland species composition is strongly dependant on precipitation amounts and timing (Minnich 2008). Precipitation was low in 2006 and 2007 and treatment effects were either small or not present. Water is commonly the most limiting resource in semi-arid grasslands of California and therefore the delay in response of natives to treatment may be driven more by precipitation in those years. If the season following the fire is not favorable to natives, management results may be discouraging. However, continuing management actions into the next season can increase success.

While we did see an increase in native species richness and cover under both management strategies, the richness is low when historical species lists are considered. This could indicate that necessary conditions for the germination of additional species may not have been met or that the seed bank is limited. Alternatively, we may not have followed these plots long enough for native, late succession species to respond. Many of the natives that responded to treatments are known fire followers; it is possible that with more time, other later succession species could increase in cover.

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Quelling Urban Invasions: Effects of *Genista Monspessulana* and *Delairea odorata* Control in Habitat Fragments.

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Abstract

Conditions in urban habitat, including fragmentation, disturbance, and increased vector abundance, are often exploited by invasive plant species. Urban conservation efforts frequently emphasize invasive species control. This paper investigates *Genista monspesssulana* removal from grasslands and *Delairea odorata* control in willow scrub in San Francisco, United States. Mapping of treated and invaded areas reveals changes in focal species distribution, while also producing an updatable GIS. Vegetation sampling was conducted in treated and invaded areas as well as sites with no history of focal species invasion (natural sites). The extent of each focal species was reduced by approximately 60% in the studied areas. Results confirm that treatment of *G. monspesssulana* and *D. odorata* significantly increases diversity values, including native cover, richness, and Simpson's diversity. However, treatment does not restore natural levels of diversity values, indicating that other invasive species take advantage of restoration efforts. Treatment increases both the abundance of characteristic natives and other influential invasives in the studied habitats. Control alters functional group representation, restoring some structural diversity. However, these benefits are qualified by the increased abundance of non-native forbs and grasses.

Introduction

Despite severe environmental stress and fragmentation, urban habitat islands often support valuable biodiversity and ecosystem function. Conservation of these relictual open spaces often requires heavy, long-term management of invasive species which capitalize on disturbance-driven resource fluctuations (Alpert et al. 2000). Recognizing that unique interactions between natural conditions, human histories and management render highly variable fragments, some urban ecologists acknowledge cities as ecosystems in their own right (Alberti 2008, Newman and Jennings 2008). Under this paradigm, conservation goals and successes are evaluated with emphasis on local conditions and possibilities rather than external reference sites.

Given the time and resources dedicated to invasive species control, there is a need to study the effects of applied treatments in the urban context. *Genista monspessulana* plagues San Francisco grasslands. Since 1998 the San Francisco Recreation and Parks Department has reduced these monotypic stands by manual removal of the entire plant and limited use of the cut-and-peel method. Similarly, the removal of *Delairea odorata* from willow scrub emphasizes manual removal. Scorching of the willow includes reducing vegetation, particularly lateral runners, by as much as 80%. Woody material is stacked, while herbaceous material is bagged and removed. Regular follow-up is conducted by staff and volunteers to address seedlings and re-sprouts. This research, conducted in May and June 2009, investigates changes in focal species distributions and the response of diversity values and community composition to these treatments.

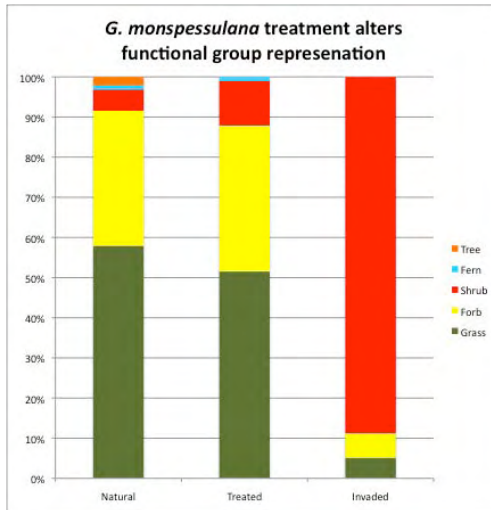
Methods

G. monspessulana was studied in grasslands of Bayview Hill and Twin Peaks; *D. odorata*, in willow scrub at Glen Canyon and Lake Merced. Mapping of treated (focal species cover > 50% prior to treatment), invaded (current focal species cover > 50%) and natural sites (no history of focal species invasion) tapped the institutional memory of SFRPD. Trimble GPS data acquired on site visits with land managers were analyzed in conjunction with 2007 air photos using ArcInfo v. 9.3.

Sampling of vegetation and environmental parameters was undertaken in natural (n = 30), treated (n = 30), and invaded (n = 20) areas of each habitat. Using six cover classes, percent cover was recorded in grassland (1m x 1m) and willow scrub (3m x 3m) plots. Statistical analysis was conducted in SPSS v. 14 and Canoco v. 4.5. Non-parametric tests (Mann-Whitney U, Kruskal-Wallis) were applied to grassland data. Parametric tests (T, ANOVA) were applied to willow scrub data after limited log and zed transformations.

Results and Discussion

The area invaded by *G. monspessulana* totaled 16.3 acres in 1998. Treatment of 9.7 acres



reduced extent by 60%, leaving 6.6 acres invaded in 2009. Remaining stands are on steeper slopes (avg 32°) than treated (avg 19 °) and natural (avg 16°) grasslands ($p << 0.001$). The increased cost of treatment and follow-up on steeper slopes likely explains this relationship.

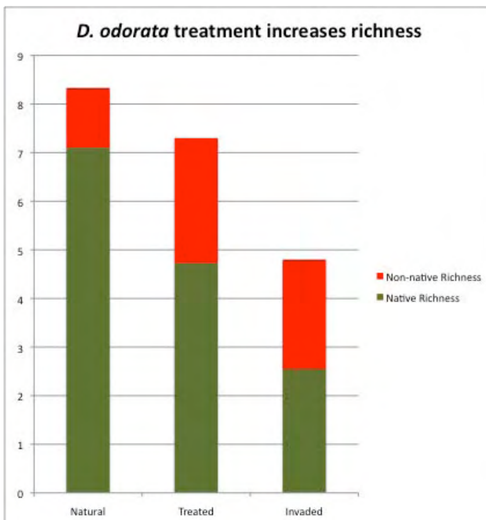
Treatment of *G. monspessulana* increases native cover, species richness, and Simpson's diversity. Species richness in treated plots (S = 12) reaches natural levels (S = 12), while invaded levels (S = 4) are significantly lower ($p << 0.001$). However, percent native richness in treated areas (34%) does not approach natural conditions (60%) ($p << 0.001$).

Treatment increases the abundance of characteristic grassland species (*Nasella* spp., *Elymus* spp., *Eschscholzia californica*, *Lupinus* spp.) to conditions found in natural plots. These gains are tempered by a significant increase ($p << 0.001$) in European annual grasses in treated (52%) over natural sites (31%). Treatment alters functional group representation dramatically (Figure 1). Shrub abundance is reduced from 87% to 11% with treatment. However, this abundance is significantly higher than natural grasslands (5%) indicating that *G. monspessulana* invasions may create beneficial conditions for shrubs. A resurgence of forb abundance also accompanies treatment. However, cover of non-native forbs, particularly *Raphanus sativa, Brassica nigra*, and *plantago lanceolata*, is higher in treated plots (23%) than in natural grasslands (4%) ($p << 0.001$).

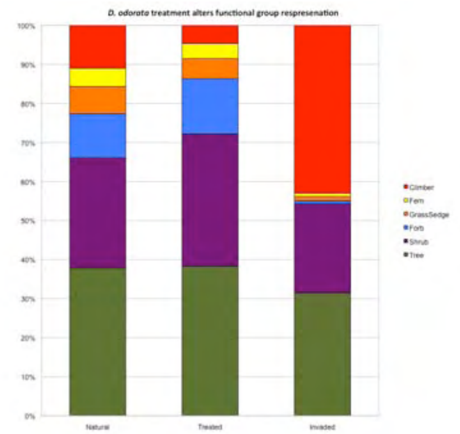
Increases in diversity values may shift further with time and management. Results indicate a need for long-term management if diversity values are to be maintained or further restored.

Prior to treatment, *D. odorata* impacted 9.7 acres of willow scrub. By 2009 treatment of 6.0 acres has reduced extent by 62%.

D. odorata control increases native cover, species richness, and Simpson's diversity. Species richness in treated plots (7) compares favorably to invaded plots (S = 5) ($p << .001$). However, natural sites host significantly higher richness ($p << .001$) and native richness ($p < .001$) than treated sites (Figure 2).



Abundance of characteristic willow scrub natives (*Salix* spp., *Rubus californica, Juncus* spp.) in treated plots (69%) is higher than in natural plots (57%). The abundance of other important invasives (*Hedera helix, Rubus armeniacus*) is significantly higher in invaded (17%) and natural (14%) plots than in treated (10%) plots. The scorching method reduces total cover in treated areas by 11% when compared to natural sites. It appears that *D. odorata* treatment also addresses other influential invasives to some degree. However, functional group analysis reveals that non-native forbs are more abundant in treated (23%) than natural (4%) plots ($p <<.001$). Again treatment reduces the influence of the focal species but provides opportunities for other non-native species. Functional group representation of treated plots more closely resembles natural plots than do invaded plots (Figure 3). Although



gains at the functional group level are not mirrored at the species level, benefits to structural diversity are evident with treatment.

Treatment of the focal species in urban fragments reduces extent while increasing diversity values and restoring some elements of community composition. Mapping changes in focal species extent prior to and following treatment produced an updatable GIS. Tracking such changes reveals the scale of invasive species control efforts within the study area. Further management, such as planting and sowing, may further restore natural levels. An increase in other influential invasives and the presence of focal species seedlings or re-sprouts in treated areas highlight the need for consistent follow-up to maintain the benefits of treatment. Such heavy management is characteristic of urban habitat conservation.

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Soil Moisture Stress Tolerance of the Leading Biofuel *Miscanthus Giganteus* is Similar to the Invasive Weed *Arundo Donax*

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Abstract

Crops grown for bioenergy production are a mandated component of California's energy portfolio. Miscanthus (*Miscanthus* x *giganteus*) is a leading bioenergy crop and is similar in habit to the invasive plant *Arundo donax* that was included in this greenhouse study. We subjected both species to soil moisture conditions of -0.3 and -4.0 MPa, standing water and a control. We constructed two groups of plants: group 1.) had eight weeks of growth followed by eight weeks under treatment conditions and group 2.) was under treatment conditions for 16 weeks. Total biomass of both species under standing water conditions was not different from the control regardless of age. However, drought did affect the two levels of establishment differently: in group 1 the -0.3 and -4.0 MPa treatment resulted in a 56% and 66% reduction in biomass respectively compared to the control averaged over both species. Likewise, in group 2 the -0.3 and -4.0 MPa treatments resulted in a 92% and 94% reduction in biomass averaged over both species. No species differences existed in drought treatments. Although our results do not indicate that miscanthus has the potential to escape and establish in upland wildland ecosystems, it does show a similar habitat preference as *Arundo donax* in lowland systems.

Introduction

California state government has set an ambitious goal of integrating bioenergy into the state's energy portfolio, which includes 20% of the state's electricity and 40% liquid motor fuel be derived from biomass by 2020 (California State Government 2006). *Miscanthus* x *giganteus* (miscanthus) is one of the leading bioenergy crops under consideration for cultivation in California's Central Valley. This non-native sterile hybrid of *M. sinensis* and *M. sacchariflorus*, has been the subject of biofuel feedstock research due to high aboveground productivity, broad climatic tolerance, efficient resource use and few natural enemies (Lewandowski et al. 2000). The lack of seed production from this triploid greatly reduces the probability of escaping cultivation and becoming an invasive pest (Barney and DiTomaso 2008). This is especially relevant as both parents of miscanthus have histories of introduction as ornamentals and have been documented as pests in many introduced regions (USDA NRCS 2009).

A qualitative analysis by Barney and DiTomaso (2008), suggested that miscanthus is a relatively safe alternative to most other non-native species for biofuel production, which was primarily attributed to the lack of seed production and lack of weediness where currently introduced – namely Europe. However, miscanthus shares many attributes with the invasive species *Arundo donax* (arundo) found in California, such as perennial habit, rhizomatous, large stature (>3m), high annual biomass production and robust vegetative propagules. Arundo was included in this study to serve as a positive control to compare stress tolerance of miscanthus against.

Ability to tolerate (or avoid) moisture stress is a critically important attribute for a plant to have in order to establish outside cultivation in California's dry summer climate in upland habitats, or a flooded condition in lowland habitats. Our experiment was designed to evaluate the tolerance of miscanthus and arundo plants with well-developed shoot and root systems and plants with weakly developed shoot and root systems to soil moisture conditions ranging from extreme drought to flooding.

Methods

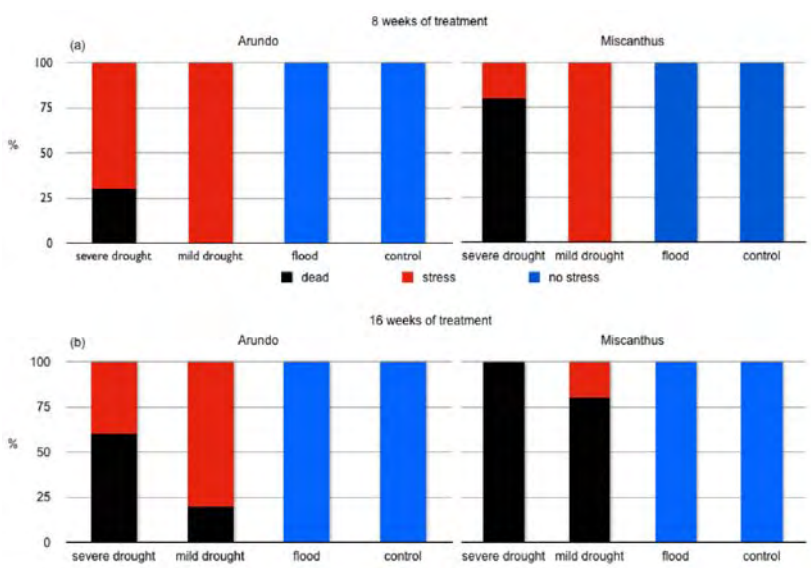
To evaluate the soil moisture stress tolerance of miscanthus and arundo we implemented a greenhouse study with a 29/18(±2)°C day/

night cycle where humidity was allowed to vary and ranged between 18 to 69%. Sodium lamps were used to maintain a 14 hr photoperiod. Rhizome fragments (20 g ± 2) for both species were buried to a depth of 10 cm in a 7.6 L pot filled with modified UC mix (50% washed sand, 50% sphagnum peat moss) at two different dates in order to create groups of plants with and without well developed shoot and root systems (from here forward referred to as group 1 and 2, respectively). The group 1 rhizome fragments were planted on August 8, 2008, while group 2 rhizome fragments were planted eight weeks later on October, 7 2008. Both group 1 and 2 had soil moisture treatments implemented on October 7, 2008.

Treatments were arranged in a randomized block design with a range of 7-10 replicates per treatment. Soil moisture treatments included flooding (≥50% moisture v/v, -0.0 MPa), mild drought (10% moisture, -0.27 MPa), extreme drought (5% moisture, -4.2 MPa) and a stress-free control (20-35% moisture v/v, -0.0 MPa). Pots were irrigated in mid-morning with drip emitters for drought treatments; two days fertigation (N:P:K = 236:52:341 ppm) were followed by one day of deionized water. Soil moisture status was measured three times per week, every other day. Plants were harvested and biomass was obtained after 16 weeks post rhizome fragment planting.

Figure 1

Species means for shoot stress level (a) group 1 (eight weeks) (b) group 2 (sixteen weeks). Colored bars indicate three levels of stress (no stress, stress and dead) within each treatment. The level of stress was observed on the shoots, and is defined as the following: No stress = no leaf rolling and no necrosis, Stress = all the leaves have some signs of rolling and necrosis, Dead = all shoots are over all brown.



All data were analyzed using a mixed model ANOVA with soil moisture treatment and species-soil moisture interaction as fixed effects. Dependent variable were checked for normality and homoskedasticity and transformed as necessary. Main effect means were compared with Tukey HSD tests.

Results

Transplant stress tolerance results

No typical signs of stress (e.g., chlorosis, leaf curling, wilting) were observed in either species or group in the control or flooded plants. However, both species in group 1 and 2 in the mild drought treatment suffered different levels of stress (Figure 1). The shoots for both species in group 1 plants showed leaf rolling and leaf necrosis with no important loss of entire shoots. As expected, the less established group 2 plants, suffered greater leaf rolling and necrosis. Group 2 miscanthus and arundo in the mild drought treatment had 80% and 20% of plants show total shoot death, respectively. The severe drought treatment exacerbated the signs of stress for both species in both groups. Group 2 had 80% miscanthus and 30% of the arundo plants shoots die. Group 2 had 100% miscanthus and 60% arundo plants have total shoot death.

Ecological traits

Total biomass of both species under flooded conditions was not different from the control regardless of age (Figure 2). However, drought did reduce the two levels of establishment differently–in group 1 the -0.3 and -4.0 MPa treatment resulted in a 56% and 66% reduction in biomass compared to the control averaged over both species. Likewise, in group 2 the -0.3 and -4.0 MPa treatments resulted in a 92% and 94% reduction in biomass averaged over both species.

Discussion

Under greenhouse conditions, miscanthus and arundo display broad tolerance to soil moisture conditions. To varying degrees, eight-week old plants (group 1) of both species accumulated biomass and generated viable rhizome fragments under low (-0.3 MPa), and extremely low soil moisture tensions (-4.0 MPa) and flooded conditions (-0.0 MPa). Arundo shoots and rhizomes survived 16 weeks (group 2) of severe drought while miscanthus shoots and rhizomes did not (data not shown). Despite this capacity, arundo does not typically establish in sites lacking supplemental moisture during summer drought in California. We showed that group 2 miscanthus displays less drought tolerance than arundo. This difference will severely limit miscanthus rhizome fragments from establishing in sites lacking supplemental moisture that may escape from cultivated lands from propagation or cultivation activities during the summer drought period. Outside the summer period, miscanthus rhizome enters dormancy after a period of frost in California's Central Valley and does overwinter in the Central Valley (D. Putnam, personal communication). In order to minimize the risk of rhizomes being lost from the biomass production chain into safe sites during the cultivation of miscanthus, appropriate measures such as described by Barney et al. (in press) should be considered by growers and resource managers.

As expected arundo rhizomes in group 1 and 2 grew to exceed 3 m tall (data not shown) in flooded conditions. Comparing total biomass, the flood treatment was not distinguishable from the control. Surprisingly, the flooded miscanthus in group 1 and 2 exceeded 2.5 m and the total biomass was not different than the control. Clearly, miscanthus has the ability to establish and vigorously grow in flooded conditions and its similarity to arundo necessitates propagation and cultivation protocols that minimize any introduction of rhizome fragments to irrigation and riparian systems. More studies are necessary to evaluate tolerance to other environmental variables (e.g., disturbance) and their interactions with competive ability.

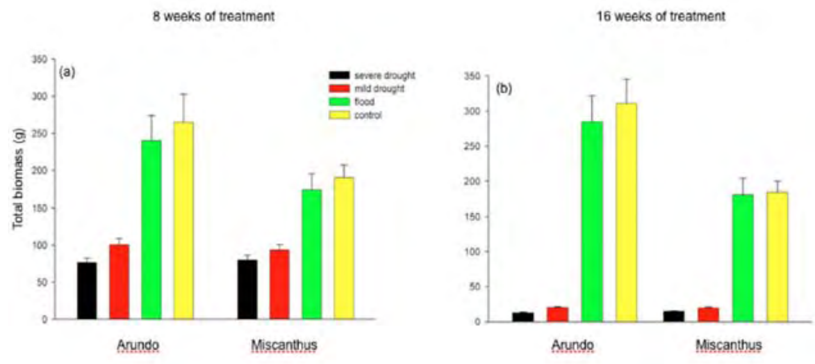


Figure 2

Species means for biomass accumulation for (a) group 1 (eight weeks) (b) group 2 (sixteen weeks). Colored bars indicate treatments that included flooding (≥50% moisture v/v, -0.0 MPa), mild drought (10% moisture, -0.27 MPa), extreme drought (5% moisture, -4.2 MPa), and a stress-free control (20-35% moisture v/v, -0.0 MPa). Error bars represent untransformed standard errors.

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Evening the Odds: Evaluating the Combined Effects of Nitrogen Fertilization and Exotic Annual Removal on Native Annual Forbs in the Colorado Desert

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Abstract

Invasive plant species and anthropogenic nitrogen deposition are altering southern California landscapes. One particularly susceptible ecosystem is the desert, where resources are naturally low and native plants are adapted to a stochastic environment. As urbanization expands into the desert, nitrogen deposition is creating a nutrient pulse that may provide an advantage to invasive species. These invasive species often have a rapid phenology, allowing them to take advantage of increased soil nutrients and moisture before natives appear aboveground. The purpose of this study is to evaluate the effects of nitrogen on native forbs in the absence of exotic annuals. Plots

were fertilized using NH_4NO_3 and exotics were removed using hand weeding and grass-specific herbicide. There were two study sites located in the Coachella Valley, CA. We hypothesized that native forbs would respond best in plots treated with both exotic removal and nitrogen fertilizer and exotics would respond best in fertilized plots without exotic removal. Analysis of the data showed a positive response of both groups to fertilization, with native cover increasing with fertilization and exotic removal.

Introduction

Exotic invasive plant species are a threat to the Colorado Desert in southern California. Plant invaders can disrupt ecosystem functioning, alter fire cycles and reduce aesthetic value of natural lands (Mack 2000 et al.). The desert has been infested with a suite of invasive annual grasses and forbs, many of which are native to Europe or the Mediterranean region. Some common desert invaders include *Bromus madritensis, Bromus tectorum, Schismus barbatus, Schismus arabicus* (referred to collectively as *Schismu*s spp.), *Erodium cicutarium*, and *Brassica tournefortii*. The desert is relatively resource-limited, with water and nitrogen availability being the main ecosystem drivers. Despite this, exotic grasses have proven able to compete with and even replace native species (Brooks 2003). However, in recent years, extended periods of drought following an extreme precipitation year appear to have shifted the invasive community towards exotic annual forbs in some areas.

Anthropogenic nitrogen deposition adds nutrients to the soil, altering soil fertility and creating a more hospitable environment for exotic species. As urbanization in California has spread towards the desert, air pollution has increased and also spread eastward. Studies show that the nearby Los Angeles Basin may receive as much as 30-50kg/ha/yr nitrogen from deposition (Fenn 2003; Allen et al. 2009). Human activities, such as the burning of fossil fuels and use of nitrogen-based fertilizers, are two main sources of nitrogen deposition. In a relatively low-resource environment, this creates a soil nutrient pulse that acts as a positive feedback for invasive species.

The objective of this research was to determine the effects of nitrogen on native annual forbs in the absence of exotic annual species. We fertilized with 25ppm NH_4NO_3, which is close to the amount of deposition experienced in the LA air basin to the west of the desert and used grass specific herbicide and hand-weeding to remove invasives. Since many areas are densely populated with exotics, it is important to uncover the effects that nitrogen deposition can have on native annuals in areas where exotic annual species are controlled, relatively uncommon, or where nitrogen deposition is particularly high. This research can also help policy makers make informed decisions for future emissions legislation.

Methods

Two field sites in the Coachella Valley in Riverside County, California were used in this study: Willow Hole and Varner Road. Both sites are situated in the far western part of the Colorado Desert, a sub-division of the Sonoran Desert and are dominated by creosote bush scrub (*Larrea tridentata*), with winter annuals present during the rainy season. The soils are sandy and the invasive species *Brassica tournefortii, Erodium cicutarium*, and *Schismus* spp. are present.

A randomized block design was set up at Willow Hole and measured in the 2008 and 2009 growing seasons. The Varner Road Site was added for the 2009 growing season and set up identically to Willow Hole. Twelve 5x5m blocks were set up in the interspace. Within each block, 4-1x1m quadrats were assigned treatments at random. In 2008, there were two grass treatments (control, herbicide (grass removal)) and two nitrogen fertilizer treatments (plus N (25ppm NH_4NO_3), minus N (no fertilizer added)). The grass-specific herbicide Fusilade II was used for grass removal. Each quadrat received one of four possible combinations of treatments (+NC, +NH, -NC, -NH). A buffer zone was added around each quadrat to prevent edge effects.

In 2009, all exotics were removed from "herbicide" plots via herbicide and hand weeding due to low exotic grass cover the previous year. The nitrogen treatments were identical to 2008.

Vegetative sampling took place at approximately peak biomass. Percent cover, density and species richness were measured in a .5m^2 subplot at the north side of the quadrat. All data included in this paper was analyzed using one-way ANOVA or Wilcoxon's Rank Sum Test in the JMP statistical package. Graphs were generated using Sigma Plot.

Results

Twenty-six annual species were recorded during the two growing seasons. As expected, exotic grass cover and density were significantly reduced by Fusilade II at Willow Hole in 2008 ($p < 0.0001$). Total exotic cover and density were also significantly reduced by herbicide and hand weeding at both Willow Hole and Varner Road in 2009 ($p < 0.0001$). In 2008 and 2009 at Willow Hole, exotic grass and total exotic percent cover responded positively to nitrogen fertilization in plots where herbicide and hand weeding were not applied ($p = 0.0401$, $p = 0.0042$) (Figure 1). In 2008, the hypothesis that native annual forbs would respond positively to nitrogen in the absence of grass was not supported. In 2009, native annual forbs did respond positively to nitrogen in the absence of all exotics at Willow Hole ($p = 0.0005$), this trend was present but not significant at Varner Road ($p = 0.0634$) (Figure 2). Native annual forbs also responded positively to nitrogen fertilization when exotics were not removed at Willow Hole ($p = 0.0433$) and Varner Road ($p = 0.0164$), although mean percent cover of native forbs was an average of 10% higher in fertilized plots where exotics were removed at Willow Hole. Native annual forb species richness tended to be higher in unfertilized plots at Willow Hole in 2009, although not significantly ($p = 0.0766$). Native annual richness at Varner Road was significantly higher in plots where exotics were removed, irrespective of nitrogen treatment ($p = 0.0256$).

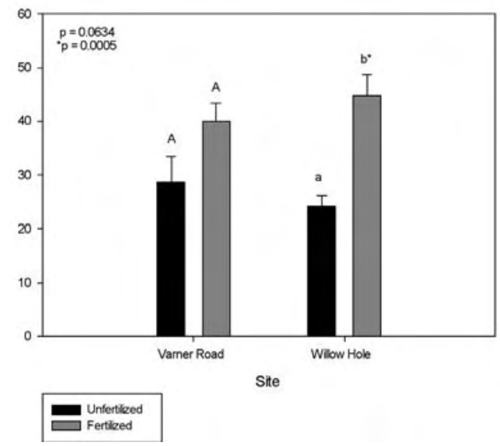

Figure 2

Native annual ford percent cover x nitrogen with exotic removal 2009

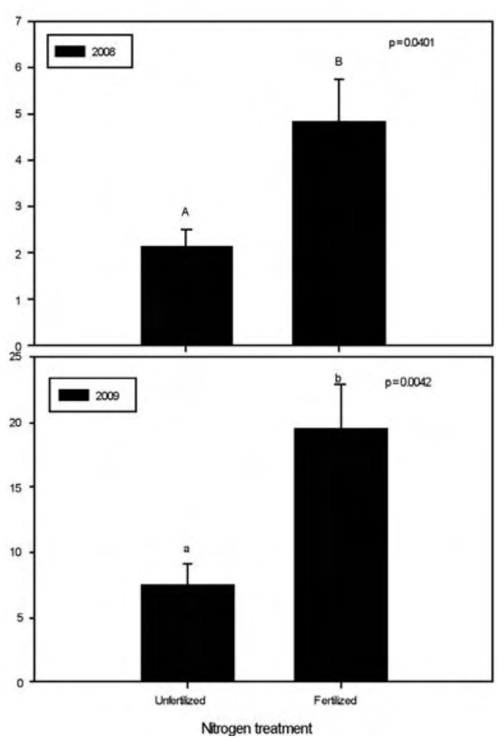

Figure 1

Willow hole exotic cover x by nitrogen without exotic removal

Discussion

During the 2008 growing season, exotic annual forbs appeared to be the dominant invasives in the landscape as opposed to exotic annual grass. One possible explanation for the lack of significant responses of native forbs to grass removal is that the density of exotic annual grasses was already so low that the effects of grass removal were minimal. Exotic grass density was sparse in most plots and likely had a relatively low competitive impact on the native annual forbs. For this reason, a hand-weeding component was added to the study in 2009.

Environmental variability likely played a strong role in the relationships that were elicited in this study. Juhren et al. (1956) demonstrated that temperature, amount and timing of precipitation could strongly influence the germination of desert annuals from year to year. In the two years preceding this study, these sites received little or no rain. Therefore, we were unable to observe the abundance of exotic annual grass at the site prior to setting up my plots, although there was anecdotal evidence that the sites were previously invaded. In both years, exotic annual cover was relatively low compared to native annuals.

In both 2008 and 2009, exotic cover was positively correlated with nitrogen fertilization. This supports the findings of previous studies (Brooks 2003, Allen et al. 2009) and demonstrates the importance of reducing anthropogenic nitrogen deposition in order to restore native vegetation in southern California. It is important to note that native annual forbs also responded positively to nitrogen and percent cover was increased to a greater degree in plots where exotics were removed. As society becomes more aware of global climate change and other threats to our natural environment, it is important to make sure that anthropogenic nitrogen deposition and its effects on soil, vegetation and other ecosystem processes is a top legislative priority.

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DPR Laws and Regulations

Laws and Regulations Pertaining to the Sale and Movement of Noxious Weeds in California

Amber Morris, California Department of Food and Agriculture, Sacramento, CA

The California Department of Food and Agriculture has identified several noxious weed species and has listed them in the California Code of Regulations (CCR), Section 4500. Any plant listed in CCR 4500 is designated as a plant pest by California state law and cannot be produced, held or offered for sale as nursery stock, as per CCR Section 3060.3. Resulting from these regulations is the prohibition of any listed noxious weed for commercial sale within California as ornamental nursery stock.

Interstate and intrastate shipments of nursery stock (from commercial and non-commercial sources) are not subject to the regulation pertaining to sale of nursery stock within the state. However, such shipments are subject to inspection upon arrival and must be found free of pests, including plants that are considered pests due to their invasive characteristics. In addition to the weed species listed in CCR 4500, the California Department of Food and Agriculture maintains an Action-Oriented Pest Rating System. This pest rating system conveys the actions that county and state agricultural inspectors should take when any pest is detected or intercepted in trade or in the environment. Shipments found containing a weed pest can be rejected under CCR 4500 or the California Food and Agricultural Code, Sections 6461.5 (for interstate shipments) and 6521 (for intrastate shipments).

The Importance of Vouchering Plant Identifications

Fred Hrusa and Dean Kelch, California Department of Food and Agriculture, Herbarium of the Plant Pest Diagnostics Laboratory. Presenters' email: FHrusa@cdfa.ca.gov, *DKelch@cdfa,ca.gov*

A voucher specimen documents a plant's presence and provides the means by which accurate identifications can be made. Voucher specimens accessioned by the herbarium of the California Department of Food and Agriculture have been identified by either an official plant taxonomist or a specialist contracted by them. This specimen can then be observed by anyone with an interest in the legality, or reality, of the species where it was found. The collection has also thus been officially recorded and the specimen retained in a permanent, publicly accessible collection and electronic database where it is available for observation or further study. In short, the vouchering of a weed sample produces a verifiable record of the plant's identity and presence.

The California Department of Food and Agriculture regulates certain plants as noxious weeds. A property can be declared a public nuisance, but a legal record of the identity and accession of a noxious weed is required before that process can occur.

While vouchering is important for noxious weeds, it is also important in all scientific investigations. Without verified, publicly available voucher specimens, scientific data collected from or about these specimens have no long-term value and indeed are actually not true scientific data in the sense that the study could not technically be repeated.

In terms of invasive species control or eradication activities, herbicide use on locations that have not been vouchered can also, in the event of a misidentification by the herbicide user, result in lawsuits. A specimen submitted to the CDFA Botany Laboratory and identified there will avoid such actions. Thus, vouchering plants provides for both scientific veracity and, where applicable, the legality of control activities.

Yeah, But What Would Aldo Think? A Look at Herbicide Ecotoxicology

Joel Trumbo, Staff Environmental Scientist, California Department of Fish and Game, jtrumbo@ospr.dfg.ca.gov

Herbicides have been an important tool in invasive weed control for many decades. In spite of their widespread use, many wildland managers still have questions about the non-target impacts these products pose. This presentation will review the basic wildlife toxicology and environmental fate information for six commonly-used invasive weed herbicides: aminopyralid, chlorsulfuron, clopyralid, glyphosate, imazapyr and triclopyr. Acute toxicity values for wildlife species will be reviewed as well as information on environmental persistence and mobility in soil, air and water. A basic understanding of this information is a critical prerequisite for land managers who walk the fine line between protecting important ecological resources and eliminating the pest species that threaten them.

New Tools

Developments in Herbicide Ballistic Technology

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An important component to all invasive weed management strategies is to effectively eradicate incipient satellite populations. However, incipient weed control can be inefficient when needing to cover large areas in difficult terrain. Herbicide Ballistic Technology (HBT) is a new technique designed to improve the efficiency of incipient weed management with accurate long-range delivery of effective herbicide doses. The technology of liquid encapsulation and pneumatic ballistics developed for recreational paintball have been adopted in the development of HBT with the basic concept of encapsulating herbicidal aliquots into 0.68 caliber gelatin projectiles that can be delivered to specific weed targets with a pneumatic applicator. HBT is a "boots on the ground" technology for assisting field crews with safer pesticide handling, improved application technique and an enhanced management strategy. Encapsulated HBT projectiles are by design ready-to-use and will eliminate the need for handling liquid pesticides in the field. The long-range accuracy of HBT allows for directed applications to multiple weed targets within a 20 meter radius from a single reference point, which improves time efficiency and also reduces disturbance to a site. We have demonstrated the ability to target incipient weed populations residing on steep cliffs and deep ravines, thus expanding the range of weed targets that would otherwise be untreatable. We have also successfully demonstrated the use of HBT as a compliment to helicopter spray operations, which can contribute to flight safety and lower operating costs. Overall, the mission for developing HBT is to advance herbicide applications in natural areas with a more refined approach (For more information, see the video at http://www.ctahr.hawaii.edu/LearyJ/videos/cal-ipc.html).

WeedSearch: A New Tool for Estimating Time and Cost of Eradication

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Abstract

The first questions often asked in planning a new weed eradication project are "How much will this cost?" and "How long will this take?" A new tool is available to resource managers to help answer these questions. WeedSearch is the first comprehensive estimating tool for the cost and time of eradicating weed populations. It is an Excel program based on the work of Australians Oscar Cacho, an economist, and Paul Pheloung, an expert in weed risk assessment. To use the model a resource manager enters specific details about the weed's biology and the amount of time invested in searching for it and the costs of control. The model outputs are estimated time to eradication, cost and probability of success. An estimate of the total number of hours spent searching for weeds and the number of hours spent killing weeds once they have been found is also simulated. We ran WeedSearch using red sesbania (*Sesbania punicea*) as a model and changed some of the input parameters to demonstrate the range of applications of this model. WeedSearch is available for free online (www-personal.une.edu.au/~ocacho/weedsearch.htm) and the soft-

ware will continue to evolve as much appreciated feedback is received by the authors.

Introduction

Land managers often struggle with the uncertainty of planning weed eradication projects. WeedSearch is a new tool available to resource managers to help answer common eradication project planning questions such as how much time, money and search effort should be expected to feasibly eradicate a weed population. This model combines population dynamics and search theory to calculate the probability that a weed invasion will be eradicated based on the amount of time invested in searching for it. It is run in Microsoft Excel and is based on the work of Paul Pheloung, Australia's Department of Agriculture, Fisheries and Forestry, and Oscar Cacho, School of Economics, University of New England, Armidale, Australia. WeedSearch is available for free for the purpose of dissemination of scientific information (software and manual available at www-personal.une.edu.au/~ocacho/weedsearch.htm) with the disclaimer that this program is a work in progress and feedback on the model will be much appreciated.

It requires input of a number of parameters relating to logistic considerations, detectability, biological characteristics, management effectiveness and economics. The values for some of these parameters may not be easy to find, but experienced weed managers may be able to come up with educated guesses and then undertake sensitivity analysis. Model inputs are listed below (more specific information can be found in the WeedSearch Software Manual, Cacho and Pheloung 2007).

Initial conditions: Total search area, density of mature plants

Biology: Pre-reproductive period, maximum longevity of seeds, seeds per square meter, mortality of first-year juveniles, size of mature plant, plant longevity, population growth rate

Economics: Fixed project costs (independent of weed density) and variable costs (dependent on density of infestation)

Management: Search pattern, searches per year, search time, detectability, search speed, effectiveness of control

Methods

We chose the management program for red sesbania (*Sesbania punicea*) in Dry Creek, located in Sacramento and Placer counties, as a test of the WeedSearch model. Red sesbania, a native of South America, was highly invasive in South Africa before biocontrol releases reduced populations there and is currently expanding its range in California along the rivers of the Central Valley (Hoffman and Moran 1998). In South Africa it was invasive along river banks and in wetlands where it formed dense thickets, restricted access to water bodies and caused increased flooding and erosion of channels (Hoffman and Moran 1991). All parts of the plant are toxic and the seeds have been shown to inhibit the germination and normal development of a wide variety of plants (Van Staden and Grobbelaar 1995).

The Dry Creek red sesbania management program began in 2004 with a Flood Protection Corridor Program grant from the California Department of Water Resources (DWR). The management area is approximately 40 miles long, from Granite Bay in Placer County to Rio Linda in Sacramento County. After the grant funds were expended in 2006, Sacramento Area Flood Control Agency requested support from local agencies and resource management groups along the Dry Creek watershed and those groups continue to make yearly contributions toward the program.

The parameters used to run the WeedSearch model are listed in Table 1, and in the WeedSearch Manual (Cacho and Pheloung 2007). The Manual is available on-line and gives a clear, easy to use description of how to run the model and interpret the results. We found that WeedSearch did not perform reliably with Excel 2007 so we recommend using Excel 2003. We began with the perennial base case model provided with WeedSearch and modified the parameters according to our experience with red sesbania in the Dry Creek watershed. Most of the values in Table 1 were estimates, or default values were used. The number of seeds per square meter was estimated from an actual count performed

Table 1. WeedSearch Model Parameters for Red Sesbania in Dry Creek Watershed	
Initial Conditions	
Total search area (ha)	98
Density of mature plants per ha	100
Maximum years	30
Biology	
Pre-reproductive period (yr)	1
Maximum longevity of seeds (yr)	10
Seeds per square meter	8,800
Mortality of first year juveniles	0.95
Size of mature plant (m^2)	1.5
Plant longevity (yrs)	10
Growth rate (lambda)	1.2
Economics	
Fixed costs	
Administration ($ per year)	10,000
Transportation to site ($ / yr)	500
Variable costs	
Labor input ($ / hr)	35
Labor input (hr / plant)	0.01
Chemical input	
($ / liter)	24
(liter / plant)	0.01
Machinery input	NA
($ / hr)	NA
(hr / plant)	NA
Management	
Search pattern	Parallel
Searches per year	2
Search time (hr / ha)	1
Detectability of adults (m)	10
Detectability of juveniles (m)	2
Search speed (mi / hr)	1000
Effectiveness of control (% kill)	99

by Frank Wallace, Sacramento Weed Warriors (unpublished data). He counted 2,200 pods on one mature plant, and multiplying by 6 seeds per pod and dividing by an estimated area per mature plant of 1.5 m² gives 8,800 seeds produced per square meter. We assumed each plant would live ten years and that the seed longevity is ten years. Recently we learned that in South Africa seed longevity is as short as three years under flooded conditions in some areas (Hoffman, J.H. pers. comm.). However, in the American River Parkway in Sacramento, red sesbania eradication programs have been underway for over ten years and seedlings are still found.

Results and Discussion

The results of the model are shown in Figure 1. The results table includes the years to eradication, total search hours, total control hours and

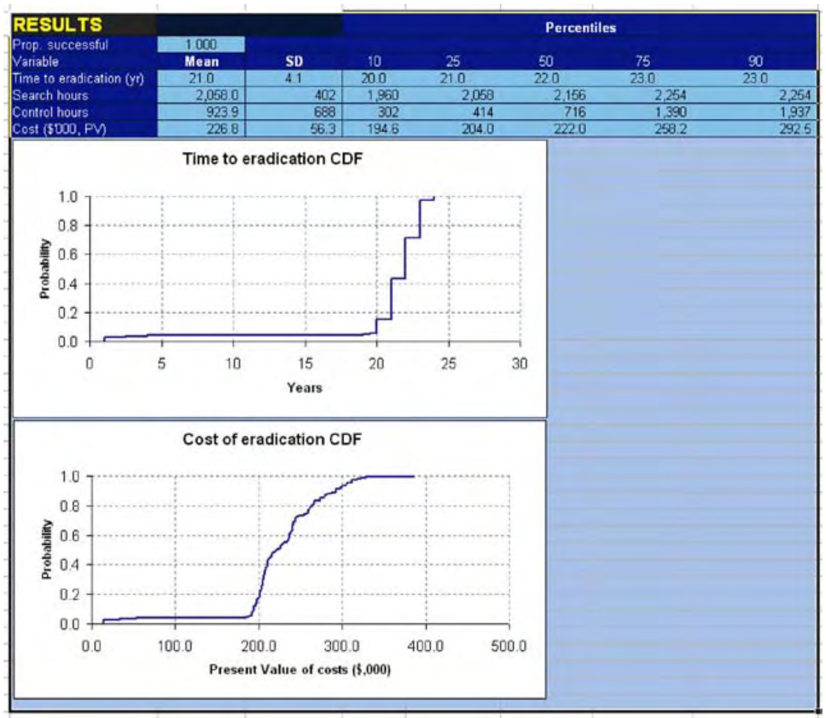

Figure 1

WeedSearch Model Results Table and Probability Graphs for Dry Creek Sesbania Example

total cost and the two accompanying probability graphs present the same information on time and cost to eradication in a more detailed manner. In the results table, the 25th percentile, for example, indicates that there is a 25% probability that eradication will be achieved in 21 years or less. Under search hours in the results table, an average of 2058 hours would be used over 21 years, so the average search labor would be about 100 hours per year. For control effort, 924 hours over 21 years would be expended, for an average of 44 hours per year. The mean cost in Figure 1 is $226,800 over 21 years, indicating an average annual cost of about $10,800. This run assumes a search area of 98 ha, therefore the cost would be about $110 per hectare per year. The probability graphs shown in Figure 1 present more detailed information than the percentiles in the results table. For example, here we can see the probability that an invasion will be eradicated in 20 years or fewer is about 18%, but if the effort is continued for four more years the probability of success increases to close to 100%.

It is easy to alter the numbers and observe how the results change. For instance, if the initial density of mature plants per hectare is reduced from 100 to 10, we found the time to eradication decreased to 19 years and cost of eradication decreased to $178,000.

The amount spent so far on the Dry Creek sesbania program is presented in Table 2. It includes the initial DWR grant (2004 to 2006), projected costs for the next ten years of treatment (2007 to 2016), actual costs for 2007 and 2008 for comparison, and an additional estimate for another twelve years based on the results of the time to eradication predicted using the WeedSearch model. There are two totals included at the bottom of the table, one is without the initial DWR grant and the second total includes the DWR grant. The original DWR grant was used to map the infestation, obtain permitting, remove mature woody sesbania, and complete one year of follow-up spray of seedlings. In comparing the two projected amounts, the WeedSearch estimate appears quite low, but is more aligned with the costs of the program after the initial mature plant removal. This indicates that in the case of this Dry Creek example, WeedSearch may be more useful as an estimate of yearly maintenance costs after a mature infestation of perennial plants has been removed, than in estimating the total costs of the eradication effort. One source of the difference may be permitting costs which are high at the beginning of a project and are not included in the model. We encourage others to experiment with this new tool, especially for planning and educational purposes and share your results with the developers.

Table 2. Dry Creek Red Sesbania Program Economics (US Dollars)

Initial DWR Grant 2004 to 2006	**[372,000]**
Yearly Program Costs (Projected in 2006) and Actual*	
2007	(41,200) **39,088***
2008	(41,200) **46,078***
Projected Future Costs (Projected in 2006)	
2009	(41,200)
2010	(24,950)
2011	(24,950)
2012	(24,950)
2013	(24,950)
2014	(24,950)
2015	(24,950)
2016	(24,950)
Total estimated 10 year cost in 2006	**298,250**
Project out to 24 years based on WeedSearch model Prediction **(12 more years after 2016 at $15,000/year)**	**180,000**
Total cost 30 year project EXCLUDING initial DWR removal grant	**478,250**
Total 30 year projected cost INCLUDING initial DWR removal grant	**850,250**

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Solar Tents – A New Twist on an Established Method for Inactivating Plant Propagative Material

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Abstract

In 2002, Stapleton et al. developed a "double tent" solarization method for disinfesting soil of weed seeds, fungal pathogens and nematodes. It generates high temperatures (>70° C = >158° F) on a routine basis during summer months in warmer areas and can eradicate pests in a single

days time. The method was approved by CDFA for regulatory prevention of nematode pests in commercial nursery soil and planting media. More recently, the technique was modified to eradicate aerial seeds of weedy plants, rather than soilborne propagules, in the Sierra Nevada foothills and Central Valley. This procedure can be of value for on-site eradication of seeds and vegetative, propagative material from localized infestations of invasive plants. The safe, inexpensive, non-toxic and effective technique is adaptable to weed infestations discovered in remote areas, or where transport of such material to disposal sites might result in unwanted dispersal en route. Experimental results of tent construction, heating characteristics and pesticidal efficacy will be discussed.

Background

The use of passive solar heating, "solarization", for destruction of soilborne propagules of weed, pathogen and nematode pests is well documented (Stapleton, 2009). The hydrothermal soil treatment has a complex mode of action, encompassing elements of physical, chemical and biological control (Stapleton et al., 2008). Although originally intended as a non-chemical alternative to soil fumigation in cultivated agriculture, solarization of soil has shown documented promise for use in wildland (Moyes, et al., 2005) and native plant community restoration efforts (Stapleton and Jett, 2006), as well as in home gardening and landscaping (Stapleton et al., 2008). Weed management is one of the most dramatic results obtained from solarizing soil. However, as solarization in open fields employs top-down heating, pesticidal efficacy is best near the soil surface and decreases with increasing soil depth.

As a method for eradicating soil pests in smaller volumes of soil, such as used in container nurseries, we began development of tent solarization. The concept was based on the demonstration of increased soil heating occurring during solarization using multiple layers of plastic film (Ben-Yephet, et al., 1987).

Solar Tents

Early results with solar tents showed that the technique was most effective when two layers of plastic film were used, with a still-air space between layers. Also, optimal heating occurred when containers of soil were elevated off the soil surface, to allow for heating on all sides of the soil masses, rather than just from the top down. Using the solar tent method, we showed that soil volumes could be heated to temperatures greater than 70° C (158° F), similar to those during soil treatment with aerated steam (Stapleton and Ferguson, 1996). Using the solar tent method, soil could be disinfested of weed, nematode and pathogen propagules during one hot, summer day (Stapleton et al., 2002). The California Department of Food and Agriculture (CDFA) subsequently approved a solar tent treatment for regulatory prevention of nematode pests in commercial nursery soil and planting media (CDFA, 2004).

Experiments to modify the solar tent concept for eradication of aerial weed propagules were initiated in 2006. Discovery of an infestation of live and skeleton plants of the Class A weed pest, Iberian starthistle (*Centaurea iberica*), in Mariposa County led to 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. Field testing showed that an adaptation of the "double tent" solarization technique could provide air temperatures sufficient to inactivate weed propagules during warm summer days (Stapleton et al., 2009). However, field and laboratory testing pointed out the critical need for moisture in the seed bags in order to imbibe propagules and obtain desired efficacy. Thermal inactivation studies were conducted on seeds exposed at 42°, 46°, 50°, 60°, and 70° C. The studies indicated that, at the higher temperatures of 60° and 70° C, seeds of both Centaurea species, as well *C. solstitialis, Brassica nigra*, and several other invasive weed species (Dahlquist et al., 2007; Stapleton et al., 2009; Tuell-Todd et al., 2009) tested could be inactivated over the course of a single day of treatment, under conditions similar to those encountered in Mariposa County.

Solar tent treatments may be of value for on-site eradication of seeds from localized infestations of invasive weed pests. It can be adaptable for use on infestations discovered in remote areas, or in other locations where attempted removal of viable seeds, or seed-bearing or vegetatively propagative material might result in unwanted seed dispersal.

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Climate Change: Impacts and Responses

Interactions Between Fire and Plant Invasions Under a Warming Climate in the Nevada Bioregion

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Climate is one of the principal factors influencing vegetation types, fire regimes and plant invasions. At any single point in time, native and non-native vegetation (as fuel) affects ignition rates and the behavior of fire, while fire behavior is a primary force in post-burn succession patterns. This feedback between fuels and fire behavior can have a major effect on the characteristics of subsequent vegetation stands, including physiognomy, species diversity, dominance of native vs. non-native species and fuelbed characteristics. Predicted future changes in precipitation and temperature regimes in the Sierra Nevada bioregion suggest a general shift of vegetation zones upward in elevation. However, other factors such as soil characteristics and topography also influence vegetation and fire regimes, and may create variable effects that do not strictly adhere to the hypothesis of upslope shifts. Shifting landscape invasibility and effects of plant invasions on vegetation and fire regimes may contribute additional complexity to these changes. The potential future scenario that emerges from these interacting factors is a shifting mosaic of vegetation zones, rather than a uni-directional upward elevational shift. In this presentation we will describe some of the potential future changes that might occur relative to vegetation and fire regimes, including the role of plant invasions, in the Sierra Nevada bioregion.

The Promise and Pitfalls of Species Distribution Modeling to Predict Future Invasions

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Abstract

Climate change is emerging as a central challenge for land management, including invasive species (IS) management. It is extremely difficult to predict which species are likely to become invasive; a rapidly changing climate makes those predictions even more complicated. Species that are invasive in places today may not be tomorrow or vice versa. There is great interest in making predictions about the future (20 year +) given directional climate change. This interest is driven by pragmatic considerations , why spend limited resources prioritizing, monitoring and controlling species that may lose their fitness in a warmer world? But are long-term predictions feasible? Can they be accurate and produce results that will alter management actions today? I address these questions with a brief review of species distribution modeling approaches and limitations in application to the problem of IS and climate change. This review highlights that incorporation of climate change projections into IS management is not straightforward and that studies to date are not quantifying uncertainty. Improvement in modeling methodologies and

assumptions is needed before widespread application of results is warranted. Distribution data is a major limiting factor to SDMs suggesting important opportunities for input by managers.

Introduction

A major thrust of work in invasion ecology is to identify which species are likely to become invasive and where. With knowledge of changing climate, the impetus to incorporate this knowledge into risk assessment is paramount. One method to predict invasions is species distribution modeling (SDM) (including bioclimatic modeling, climate envelope modeling, environmental niche modeling). While efforts to identify a connection between an organism's distribution and the climate in which they occur has had a long history of use in predicting IS (Mack 1996), efforts to predict invasions in future climates are just beginning to proliferate (Jeschke and Strayer 2008).

Ecological niche theory lays the foundation for species distribution modeling. Niche here is defined as the multidimensional environmental space in which a species can survive and grow. SDMs require input of species occurrences (latitude, longitude) and environmental data (climate, elevation, soils, vegetation) to build correlative models, which can be used to predict ranges. Models output species-specific suitability indexes for landscapes that are visualized in GIS. There are many different SDM techniques available, ranging from very simple to complex non-linear and machine learning algorithms. Some models require data on both presence and absences of species, and others require data only on presences.

SDMs, while powerful tools for synthesizing the broad geographic ranges of species, also have many limitations that have been widely discussed (see for example Pearson and Dawson 2003). Predictions into novel climate (climate change) and space (invasive species) are the most challenging applications because they require that models be extrapolated beyond the conditions in which they were calibrated. The degree to which models can perform well in these applications is unclear. My purpose here is to highlight these limitations and the extent to which they can be dealt with methodologically.

Limitation #1 – Models are not necessarily transferable in space and time

Transferability is essential feature of SDMs to predict IS distributions in current or future climates. Transferability asks whether a model calibrated in one domain can be extrapolated to novel situations. There are a number of reasons why SDMs may not be transferable. First, SDMs use empirical data to set the fundamental limits of a species range. However, empirical data reflects realized niches – a product of variables beyond climate and other environmental factors. For instance, biotic interactions, dispersal abilities and disturbance set limits on populations. SDMs can capture these factors if they correlate well with environmental gradients, but this is unlikely to be the case when models are applied to novel space and time. Consequently, models may over-represent a potential range because they are not capturing the limitations imposed by the biotic community. Or they may under-represent a potential range because the species can tolerate a wider range of environmental space than its empirical distribution suggests.

The predictive ability of a model across novel space can be tested using independent datasets, such as the distribution of an IS in its introduced and its native range. A few studies have tested whether datasets calibrated on native ranges can predict invasive ranges (Broennimann and Guisan 2008). The results are equivocal with research suggesting success for some species and failure for others. It appears that outcomes are species specific and dependent on some combination of the following factors: the quality of the distribution and climate data, the extent to which the invader is at equilibrium in its introduced range, niche overlap between the native and introduced ranges, the similarity of biotic interactions between ranges and the modeling technique.

Testing the accuracy of predictions in novel climates is more challenging. Independent datasets of species distributions in the future are not available. Inventive studies that have explored this question find that accuracy declines when applied to a different time period (Araujo et al. 2005, Hijmans and Graham 2006). A further challenge in using SDMs to project climate change impacts is that "no-analogue" climate conditions are expected to occur across much of the landscape (Fitzpatrick and Hargrove 2009). Different modeling algorithms extrapolate into novel environmental space differently and these extrapolations may not be ecologically meaningful, thus providing spurious results.

Limitation # 2 - the SDM technique used affects the outcome

Studies show very clearly that results differ depending on the modeling technique used, but it is not clear which techniques should be used in which applications. Evaluations of modeling performance are nascent (Elith and Graham 2009). Results suggest that more complex techniques (i.e., ANN, MAXENT) show more predictive accuracy than simpler techniques (i.e. DOMAIN, BIOCLIM) (Araujo et al. 2005, Elith et al. 2006, Hijmans and Graham 2006). What these limitations mean methodologically is that to create a robust measure of an IS range it is necessary to chose modeling techniques thoughtfully and to use more than one technique to bracket uncertainty.

Limitation # 3 – the projections of global climate models vary

When incorporating climate change into modeling exercises, there are additional uncertainties to confront. Like SDMs, global climate models, of which there are more than 20, vary in their projections for future climate. Depending on the GCM used and the emissions scenario, the magnitude of temperature increase varies. Inter-model variations are even starker for projections of precipitation change, which range from significant decreases to significant increases for the same location. To address these limitations is it important to use multiple climate models and emissions scenarios to bracket uncertainty. A good example of how to use an ensemble of climate models can be found in Klausmeyer and Shaw (2009).

Conclusions

This review highlights just some of the many limitations of the SDM approach for predicting IS distributions in the future. Given the limitations, a conservative conclusion is that results should be very cautiously applied. For species of serious concern, physiologically based mechanistic models will likely provide more accurate predictions. A review of 20 studies that used SDMs to predict invasions shows on average 2/3 used only one modeling technique and one climate model. This indicates that researchers are not currently quantifying uncertainty in a robust way, making it tenuous for managers to apply these findings. While advances are made in niche and climate modeling, managers would do well to use established best management practices for early detection and intervention of potential invasive species keeping in mind a warming trend and to implement protocols for gathering and sharing precise location data on invasive species occurrences. At the core, SDM modeling can only improve with better data availability.

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Climate Change and Protecting Biological Diversity: Implementation of California's Report on Adaptation Strategy

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The Governor's California Climate Adaptation Strategy (2009) sets forth goals and tasks to reduce impacts on the State's extraordinary biodiversity. The specific strategies seek to maximize long-term species protection while recognizing fiscal limitations in all conservation sectors. The presentation will focus on implementing actions relative to strategic land and habitat protection, managing and restoring natural resources and research. Relevant and transferable examples from the experience of State Parks and the Department of Fish and Game will be discussed, including reducing environmental stressors and restoring ecological function.

Density, Compensation and the Persistence of Yellow Starthistle Populations Across California

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Abstract

We used a field experiment to explore the factors that regulate the growth and persistence of yellow starthistle (*Centaurea solstitialis*) populations across its full longitudinal range in California. Density-dependent processes at all life-stage transitions can decouple seed input from germination, survival, fecundity and population growth, with implications for the role of seed predators (biocontrol agents) to control these invasions. We conducted a seed addition experiment (0, 50, 500 and 1000 seeds added to 0.25m^2 plots) and coupled it with an observational study within established invasions to estimate seed rain, seedling recruitment, mortality and fecundity at natural *C. solstitialis* densities. Seed limitation occurred in both experimental and observational plots in all populations. Density was correlated with mortality only in the site with the highest seedling density. The seed limitation that was evident at the seedling stage persisted to flowering. Seed-limited populations ought to be highly sensitive to losses to seed predators, however, flowering plant density was decoupled from seed production by a strong compensatory response in the surviving plants. Seed production was nearly constant in plots across all seed addition levels (50, 500, 1000 seeds added), regardless of flowering plant density. Thus seed predator biocontrol agents reduce flowering plant density but not the persistence of the population over the long term.

Introduction

A central goal of invasive plant management is to understand the factors that regulate the recruitment of new individuals into a population because such information improves out ability to manage invasions. In some plant populations, there is a strong relationship between the number of seeds entering a patch and the number of seedlings and ultimately, flowering plants, that establish. In such populations, recruitment is "seed limited" and any increase or decrease in seed production is expected to have a concomitant effect on recruitment (Crawley 1989, Louda and Potvin 1995). But the link between seed production and seedling abundance is rarely straightforward. Three processes have the potential to decouple recruitment from seed production, a scarcity of germination microsites, granivory and density dependent mortality. When plants produce more seed than there are germination microsites available, increasing seed input will not lead to an increase in seedling recruitment. Seed predators may strongly mediate recruitment but only when they remove seeds that are otherwise likely to have germinated, i.e., in populations in which recruitment is seed limited (e.g., Louda 1982, Louda and Potvin 1995). Finally, strong density-dependent mortality at any life stage prior to reproduction can reduce or even eliminate gains in recruitment that are the result of higher seed input.

All of these factors ought to be especially important to species with an annual lifecycle because recruitment is entirely from seed. Yellow starthistle (*Centaurea solstitialis*), one of the state's most problematic invasive species and which is still expanding its range (Pitcairn et al. 2006), is one such species; therefore understanding how these factors interact is essential to managing yellow starthistle invasions in California.

Methods

We used a combination of experimental and observational studies to explore the role of seed availability, density-dependent processes and seed predation in three yellow starthistle invasions across California. At the scale of a species geographic range, the degree to which any one population is seed or microsite limited will likely vary as environmental conditions that are relevant to germination change. We therefore repeated these experiments in coastal and interior grasslands and along the leading edge of the invasion in the mid- to high- elevations of the Sierra Nevada mountains.

We conducted a seed addition experiment in uninvaded areas (seed addition levels: 0, 50, 500, 1000) and caged half the plots to exclude vertebrate granivores. By following the plants for their entire life cycle, we were able to determine if density significantly reduced the survival of seedlings or fecundity. In addition, we measured natural seed production, seedling recruitment and survivorship in established invasions at each site. We asked the following questions: 1.) How is seedling recruitment influenced by seed input and post-dispersal granivory? 2.) Does density influence mortality and therefore the number of plants that reach flowering? 3.) Does density influence fecundity and therefore the number of seeds produced per plot? and 4.) Do the results vary across a broad geographic range?

Results

When seedling recruitment is limited by seed availability, the cumulative number of seedlings that establish will increase as the number of seeds added increases. Alternatively, when there is a limited number of germination microsites, higher levels of seed addition will not result in greater seedling establishment. The number of seeds added had a strong initial effect on seedling recruitment at the Coast and Interior sites. However, there was no difference in the number of seedlings that recruited in plots with 500 seeds and those with 1000, indicating that at 500 seeds, recruitment into the populations at the Coast and Interior sites had become microsite limited.

We found a different pattern at the Sierra site. Seedling establishment continued to increase with increasing levels of seed addition indicating that the threshold between seed and microsite limitation is greater than 1000 seeds per $0.25m^2$ plot. Further, at any given seed addition level, the total number of seedlings that established was much higher at the Sierra site than at the Coast and Interior.

There was strong agreement between the results from our experimental and observational plots. Observational data were particularly revealing at the Sierra site where natural seed rain was much higher than in the experimental plots (up to 21,000 seeds per $0.25m^2$ plot). Even at these very high natural seed input levels, seedling recruitment showed a stronger response to seed input than did plots at either the Coast or Interior sites, i.e., even at these exceptionally high seed inputs, seedling recruitment was still increasing.

Native vertebrate granivores were actively feeding at the sites and were unable to enter the caged plots. However, this feeding had no effect on starthistle recruitment in any population.

If seedling survival is regulated by density dependent processes we ought to see a higher proportion of plants dying in plots with higher seedling density. Although seedling mortality was high, it did not increase with density at any site in the experimental or the observational plots with the one exception of the Sierra site where seedling density was considerably higher than at either of the other two sites.

The number of plants that survived to flowering in experimental plots followed the same pattern as seedling recruitment, i.e., the number of flowering plants continued to increase as the number of seeds added increased at the Sierra but saturated at 500 seeds added at the Coast and Interior sites. The mean number of flowering plants per plot was much higher at the Sierra site and there was no difference between the Coast and Interior sites.

Although density had no effect on survival, it did have an effect on fecundity (except at the Coast where density was very low). Flowering plant density reduced the mean number of seeds plants produced at the Interior site and the Sierra site. This effect of density on fecundity yielded an interesting result. When we compared the number of seeds produced on a per area basis (0.25m^2 plot), we found no significant effect of seed addition level on the number of seeds produced per plot: Seed production in the plots to which we added 50 seeds was not lower than in plots to which we added 500 or 1000 seeds. These results are consistent with other work on *C. solstitialis*. Garren and Strauss (2009) found that in plots in an old field, a few large plants produced as much seed as many small plants, resulting in a constant final yield in seed production, similar to our study across a range of environments.

As for comparisons among sites, again we found that there was no difference in the number of seeds produce per plot between the Coast and Interior populations and that seed production in the Sierra population was significantly higher.

Discussion

The success of biocontrol agents can be measured by the degree to which they reduce flowering plant density and/or local seed production, which is strongly linked to the long-term trajectory of the local population. Our data show that seed limitation occurred at all sites and persisted through to the flowering stage, meaning that seed predators have the potential to reduce flowering plant density all three sites. Although our study was not designed to test this possibility, the frequency or intensity of the seed limitation that we observed may be attributable to seed predation by the established biocontrol agents *Eustenopus* and *Chaetorellia*. But the magnitude of a seed predator's impact would vary among sites due to the presence of microsite limitation in the Coast and Interior but not the Sierra. For example, in plots with high seed input (1000 seeds), seed predators that consumed half of the seeds would significantly reduce flowering plant density at the Sierra site, but would have no effect at the Coast and Interior, whereas in plots with low seed input, seed predators will reduce flowering plant density at all sites. However, increases in seed input (conversely, reductions in seed input due to seed predation) did not affect the total number of seeds going back into the plot. Thus, in our populations seed predation would be expected reduce flowering plant density, but not to lead to overall population declines.

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Team Arundo del Norte: Lessons Learned from a Coordinated Approach to Weed Management

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Team Arundo del Norte (TAdN) was formed in 1999 around the concept that sharing common resources in the battle against giant reed invasion would help do more with limited funding. For the past eight years, TAdN has conducted a program involving partner organizations in nine watersheds spanning the Sacramento and San Joaquin Bay-Delta region. The program focused on integrating several aspects of the work of controlling an invasive, including: coordination and outreach, especially sharing of expertise among partners; regulatory compliance and attempts at regional permitting; eradication methods research to get answers weed managers needed most; technical support for weed mapping and monitoring; and mapping of the overall region's Arundo problem with prioritization of future efforts. This program ends in 2009 and this presentation shares our eradication accomplishments as well as the benefits and challenges encountered by program coordinators, partners, and research scientists. We will conclude with lessons learned and recommendations for future efforts

Lots of Land, Lots of Weeds, and Little Time: Large Scale Baseline Weed Mapping

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Abstract

The first step in a successful invasive weed management program is obtaining an inventory and baseline map of weeds within the land management area, which can be difficult for large-acreage land stewards. Knowing the identity, location and relative abundance of weed species is essential to planning strategy as well as securing funding and support. Budget constraints require an efficient method to survey as much area as possible in the least amount of time, while still providing the necessary information required to develop weed management strategies.

We utilized a highly efficient data collection method to map a total of 65 invasive plant species on the 23,000-acre Peninsula Watershed in San Mateo County, owned and managed by the San Francisco Public Utilities Commission. Field work was conducted by six people for ten days. Results of the mapping were used to identify well established species and early invaders, demonstrate observable trends, develop priorities for control and recommend changes to current management regimes.

Introduction

The first step in managing weeds in an area is to obtain an inventory and baseline map of weeds. Knowing the identity, location and relative abundance of weed species is essential to planning strategy as well as securing funding and support. However, this can be difficult for large-acreage land stewards. Budget constraints require an efficient method to survey as much area as possible in the least amount of time, while still providing the necessary information required to develop weed management strategies.

We completed a baseline weed mapping of 65 invasive plant species on the 23,000-acre Peninsula Watershed owned and managed by the San Francisco Public Utilities Commission.

Methods

The Peninsula Watershed is located in north-central San Mateo County, west of Interstate 280 and east of Skyline Ridge. The Peninsula Watershed includes the San Andreas Reservoir, Upper and Lower Crystal Springs Reservoirs and Pilarcitos Reservoir. Land uses of the Peninsula Watershed are primarily water collection, storage, delivery and associated facilities and open space. Other land uses include Crystal Springs Golf Course and PG&E utilities and transmission rights-of-way. Surrounding land uses to the north and east are primarily residential and include the communities of Pacifica, San Bruno, Millbrae, Burlingame, Hillsborough, Belmont, San Mateo, San Carlos and Woodside. There are several sensitive natural communities in the Watershed including serpentine bunchgrass grassland, valley needlegrass grassland and northern maritime chaparral, as well as riparian and wetland vegetation communities. Several special-status plants are known to occur on the Watershed.

This survey is considered a reconnaissance-level survey or "exploratory" survey (Rew and Pokorny 2006). An exploratory survey is suitable for situations when little or nothing is known about the location and types of NIPS in relatively large areas because they are efficient and cover large areas. The purpose of an exploratory inventory/survey is to search as many acres as possible in the least amount of time, while still providing the kinds of basic information needed.

Surveys were conducted by six people in September/October 2008. We worked in two teams of three people or three teams of two people, depending on the terrain. We surveyed for a total of ten days and worked ten hour days, for a total of 600 person hours for the field effort. Surveys consisted of a combination of windshield surveys and walking surveys. In grassland and other accessible areas, we walked wandering transects, 50 to 100 feet apart.

Data collected during field work included attributes as specified by the California Weed Mapping Handbook (CDFA 2002) and the North American Invasive Plant Mapping Standards (NAWMA 2002). All data collected was point data, no polygon data was collected. Data was collected using handheld Garmin GPS units and paper data forms. The data from the forms was hand entered into Excel spread sheets, then the table was joined to the GPS locations using the Waypoint number into GIS. A data point was collected for each NIPS occurrence. Data was collected using feet and acres.

Results and Discussion

A total of 3,710 occurrences of 65 weed species were mapped in the Watershed comprising 183 acres of total infested area. The five species with the highest number of occurrences are jubata grass (*Cortaderia jubata*), bull thistle (*Cirsium vulgare*), yellow starthistle (*Centaurea solstitialis*), poison hemlock (*Conium maculatum*) and teasel (*Dipsacus sativus*). The five species with the highest infested area are yellow starthistle, velvetgrass (*Holcus lanatus*), Italian thistle (*Carduus pycnocephalus*), blue gum seedlings (*Eucalyptus globulus*) and jubata grass.

There were several areas in the Peninsula Watershed that had large concentrations of weeds and are generally characterized as weedy or ruderal. Control and management efforts would likely not be effective in these areas. The most infested areas include the north, east and south sides of San Andreas Reservoir; Skyline Quarry; lands immediately adjacent to Interstate 280; and the east shore of Lower Crystal Springs Reservoir near Highway 92. Overall, larger numbers of weeds were present in areas with higher levels of human activity. Large concentration of weeds were found along road edges, fuel breaks, reservoir margins, staging areas, dam edges, pipeline right-of-ways, buildings, and culverts. Some Watershed roads had patches of target invasive plant species along their entire length. However, many weed occurrences were only near the roads and their occurrence typically decreased as distance from the road increased.

Areas in the Peninsula Watershed that had low numbers of weed infestations were identified. These include Perimeter Road; Pilarcitos Creek; Spring Valley Ridge; Fifield Ridge; Portola Ridge; Sawyer Ridge; Sherwood Point; Cahill Ridge (with the exception of Cemetery Gate and the vicinity); and Old Cañada Road. Efforts should focus on treating weed occurrences in these areas and preventing further spread.

In consultation with SFPUC staff, we developed a list of general weed management actions, based on the results of our large-scale weed mapping.

Recommendations focused on:

- **Sensitive Habitats**: Invasive weed species control in selected habitats to protect sensitive biological resources including special-status plants and wildlife, and sensitive natural communities
- **Distribution Centers**: Invasive weed species control in high traffic areas to prevent the spread of weeds from highly infested areas to less infested areas

- **Outliers and Defensible Spaces**: Treatment of specific satellite or outlier weed occurrences to keep relatively pristine areas from becoming infested
- **Contractors and Crews**: Training and best management practices to prevent the introduction, spread, and establishment of invasive weed species in the Watershed
- **Management Activities**: Modifications to routine Watershed management activities to reduce the expansion of invasive weed species
- **Survey and Reporting**: Central database development and implementation to report, treat and maintain control of infestations. Continued reporting of invasive weed species occurrences to detect new invaders, evaluate control programs and to monitor changes in invasive weed species distributions

Overall, the large-scale weed mapping approach was successful and provided baseline information about the type and location of invasive weeds on the Watershed. This baseline mapping will be used to guide both land management decisions and the development of a prioritized weed management strategy and control program.

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PG&E's Approach to Management of Noxious Weeds in Sierra Nevada Watersheds and Expanding our Invasive Species Efforts through Strategic Planning

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Abstract

Monitoring of natural resources at the landscape level is a challenging task. PG&E's hydroelectric watersheds, located throughout the Sierra Nevada Mountains of central and northern California, collectively represent tens-of-thousands of acres where ecological monitoring activities are required by the Federal Energy Regulatory Commission (FERC). This includes control and monitoring of noxious weeds.

PG&E's corporate-level strategy for invasive species control focuses on a number of key components including partnering with stakeholder groups like local Weed Management Areas (WMA's). Employee training, procurement strategies and including potentially important invasive weed issues in routine project environmental screening are other elements of this strategy.

Introduction

The purpose of this paper is to describe an ongoing private sector weed control program with a large landscape-level scope in northern and central California. I will present one watershed project in some detail as an example of our approach, methods of data capture and degree of success to date. I will also discuss PG&E's efforts at developing an invasive species strategy throughout our service territory.

Weed Control on Hydro Power Projects

PG&E currently operates 26 FERC licensed hydroelectric power projects in California. Collectively these facilities generate 3,900 Megawatts of renewable clean energy for residential and commercial customers. Most of these projects were built more than fifty years ago. Some have recently received new 30-year operating licenses while others are currently in some stage of the relicensing process.

PG&E's hydroelectric power projects often involve National Forest System Lands. In 1999 an executive order was signed by President Clinton that called for efforts to prevent spread of noxious weeds on federal lands (Fed. Register, Volume 64, Number 25, 1999). In 2000, the Pacific Southwest Region of the Forest Service published its noxious weed strategy (USDA 2000) and this informed the completion one year later of the Sierra Forest Plan Amendment that rewrote many of the Natural Resource Management Plans for National Forests in this region and included directives for controlling and preventing spread of noxious weeds (USDA 2001).

Section 4(e) of the Federal Power Act (16 U.S.C. 791-828c; June 10, 1920, as amended) directs federal agencies to provide written comments to FERC during the licensing process addressing measures needed to reduce potential environmental effects on the public lands and resources under their jurisdiction.

Mokelumne River Project

PG&E received a 4(e) condition for noxious weed control in 2001 for the Mokelumne River hydroelectric project (FERC 137). The requirements of this condition include:

- Inventory and map noxious weeds occurring on USFS lands within the project boundary
- Implement a control and prevention plan
- Annually monitor all mapped occurrences
- Repeat baseline inventories every three to five years

The Mokelumne River Project is located on the North Fork Mokelumne River in Amador, Alpine and Calaveras Counties, California and includes lands within the Eldorado National Forest.

PG&E completed a weed inventory and mapping effort on the Mokelumne Project in 2002. Mapping was based on submeter accuracy global positioning system (GPS) technology. Occurrences were mapped as either polygons (larger, multi-species infestations) or point features (small, single species infestations) and a wide range of attribute data was collected for each. Nine species were selected for control and these accounted for approximately 11.4 acres of infestation distributed over a working area of more than 4,000 acres.

Prior to start of control measures in 2004 the baseline inventory data was transferred to field computers running mobile geographic information system (GIS) software. Details of this mobile GIS data management approach were presented by Fry and Ball (2008).

Starting in 2007 we modified our mobile GIS platform to achieve greater efficiency. This involved use of a grid overlay where each cell of the grid equals a "pre-mapped" regularly shaped GIS polygon. Attribute data from previously mapped features were transferred to the appropriate cell or cells within the grid. These data are accessible electronically from the field computers which are also used to update (edit) the data. Colors distinguish the dominant species within each cell and cross-hatching indicates presence of multiple species within a cell.

This approach allowed us to eliminate time spent mapping new weed occurrences or modifying the geometry or location of existing infestations as they respond to control treatments or otherwise change over time. The grid requires only that the attribute data associated with each cell be regularly updated.

Results of Weed Control Efforts

A comparison of data from the first year of control treatments (2004) with data from 2007 (following completion of the second comprehensive inventory) revealed the following:

- Number of cells with multiple weed species present declined from 60% to less than 30%
- Cover values for target weeds within occupied cells also declined, with 95% of occupied cells having weed cover values in the "<1%" category
- Infested area dropped from 11.4 to 2.7 acres (75% reduction).

The declining trend in distribution of target weeds across the project area has continued through 2009 as shown below:

- In 2008, a total of 229 cells remained occupied (16% reduction over 2007 levels)
- In 2009, 211 cells were occupied (~8% reduction over 2008 levels)

Treatments

The Eldorado Forest has approved the use of foliar herbicides, but not pre-emergent herbicides, for control of weed species occurring on National Forest System Lands. The spring chemical treatments for private land consisted of a mixture of Garlon 3A, Roundup Pro, and Hasten. Treatments on USFS land included a mixture of Accord, Hasten and Transline. Milestone is used for fall treatments on PG&E lands.

At present about two-thirds of occupied cells are treated with herbicides while one-third are treated manually.

Scope of Current Work

PG&E has weed control programs underway in three of its hydro watershed areas (Feather River watershed, the Mokelumne River watershed and the San Joaquin River watershed). In addition weed control plans have been written or are being developed for projects in the Pit River, Stanislaus River and Kern River watersheds. Collectively these projects involve tens-of-thousands of acres of watershed lands, with more to be added as other projects complete the relicensing process.

Beyond Compliance-based Weed Control

In 2007 PG&E's "Environmental Visioning Workshops" identified invasive species as an issue of importance to PG&E. Since then we have been working on the framework of a strategy for invasive species control that touches many of the operational elements of our business and reaches into every corner of our service territory.

The Elements of our Weed Strategy

Improve training for our crews – Environmental training for PG&E employees will be updated with information on invasive species.

Incorporate standardized BMPs into construction and maintenance activities – In 2009 with the assistance of ICF consultants (previously ICF-Jones and Stokes) PG&E completed a review of literature to identify and catalogue best management practices for control of invasive species in California.

Improve access to commercially available weed-free products – Access to suitable weed free products for site stabilization and restoration is hampered by lack of certified vendors and by constraints within PG&E's own sourcing practices. We are currently working to better inform our crews and streamline access to these resources.

Incorporate GIS-based data into project planning – In 2009 CDFA provided us with GIS shapefiles for known A-rated weed species occurrences in California. Merging these data with our own enterprise GIS system allows project planning to consider the potential risk of A rated species within a work site.

Hazard Assessment Critical Control Point planning – The USFWS has adopted HACCP planning for use with programs of invasive species control. In 2008 we applied this process to evaluate risk of weed introductions on a Safe Harbor property in Santa Clara County.

Increase involvement with State and local action groups – Weed Management Areas (WMAs), Early Detection/Rapid Response networks, and organized efforts like the California Department of Food and Agriculture's Stop-the-Spread of Yellow Starthistle project are examples of opportunities we have identified for getting more involved with others to help make a difference.

Incorporate PlantRight recommendations for landscaping – PG&E properties should lead by example choosing landscaping that features native species with lower water requirements and materials that are certified weed free.

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Partnerships and Incentives

Can a Spiny Shrub Prick the Collective Ecological Conscience?

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Abstract

The woody legume gorse (*Ulex europaeus L.*) has colonized many sites along the Pacific Coast of North America. In the community of Caspar, Mendocino County, California, European settlers planted the spiny shrub as an effective hedgerow over 150 years ago and gorse has long since become a well established resident, spreading into adjacent coastal grasslands, scrub and forests. Gorse alters soil chemistry through nitrogen-fixing symbiosis,and its dense, sprawling growth reduces native plant cover – threatening a number of rare taxa – increases wildfire potential and interferes with human recreational opportunities. Past efforts to contain or eradicate gorse on both public and private lands have failed due to lack of political consensus and long-term strategic commitment. Over the past several years, the Caspar Community and residents have backed gorse containment efforts by the California Department of Parks and Recreation, the California Department of Transportation, the Mendocino Fire Safe Council and the Mendocino Coast Cooperative Weed Management Area (MCWMA), yet funding gorse control efforts remains a significant challenge.

The MCWMA has developed an innovative multi-objective strategy to link targeted funding sources to components of a coherent strategy. While this program has achieved some early success, budget concerns and lack of political consensus remain huge challenges to the integrity of affected ecosystems. Long-term success will likely depend upon increasing community support for gorse management under a broader umbrella of local ecological sustainability and conservation.

Gorse in its Native Land

Gorse is leguminous shrub native to northwestern Europe. It grows to five meters tall, with leaves hardened into spines, branch tips into thorns. Seedlings are unarmed and palatable to livestock. Plants mature within 18 months, producing yellow pea-type flowers, maturing into seed pods that rupture explosively, scattering seeds at about 600 seeds/m^2/yr. Rich in volatile oils, gorse is a well-adapted to fire. In its native range, gorse is valued as a hedgerow, for soil enrichment, fodder, and fuel.

Gorse as an Invasive

Gorse was intentionally introduced into many British colonies, thriving and spreading in Australia, New Zealand, Chile and western North America. In California, gorse is patchily established along the North Coast and in the northern Sierra Nevada foothills. In Mendocino County, the largest infestation is in Caspar, including a significant population at the waste transfer station, a total area of about two square miles. Within the core infestation, gorse is also patchily distributed, covering a net area of about 1000 acres, infesting dry, salt-encrusted bluff crevices, marshes, stream corridors, open grassland, forest openings and coastal scrub. Local impacts include wildfire risk, restricted access to recreation and agricultural land, loss of habitat and nitrification of soils.

History

In the wake of the Gold Rush, a sawmill opened at the mouth of Caspar Creek in the 1850s, and local agriculture expanded apace to feed the workers. The Jefferson/Tregoning family ran a cattle ranch near Jug Handle Creek and the terraces were tilled for vegetables. Local legend holds that gorse was introduced to contain the cattle on Jughandle Creek ranch; it was well-established by the 1930's, as it was sporadically along the Pacific Coast. In 1936, gorse fueled the burning of Bandon, Oregon, resulting in eleven fatalities and $3M damage. Perhaps as a result of the Brandon Burn, CCC and WPA crews were employed to "eradicate" gorse from Caspar during the 1930's. However, the ecology of gorse was neglected and the seedbank spawned the next gorse generation.

In 1953, the Mendocino Department of Agriculture introduced the gorse seed weevil (*Exapion ulicis*) as a biological control agent. While not eliminating gorse, the insect may have slowed its spread. In 1979, State Parks initiated gorse management in the newly-acquired Jug Handle State Reserve, originally part of the Jughandle Creek Ranch. From the 1960's to 1993, various control methods were attempted and evaluated – mowing, herbicide, prescribed burning, mechanical removal, hand removal, shredding and tilling. The Mendocino County Department of Agriculture implemented an unwritten containment policy on gorse: manual removal of any gorse observed beyond two specified Highway 1 milepost markers, followed by application of the herbicide Tordon.

In 1993, State Parks implemented an integrated pest management approach: manual and mechanical removal, herbicide application, and release of the gorse spider mite (*Tetranychus lintearius*). In 1995, environmental activists criticized the timber industry for the widespread applications of Garlon on hardwoods on timberland and State Parks'use of herbicides were caught in the fray. State Parks District Superintendent Bill Berry reacted by stopping herbicide use at Jug Handle. State Parks gorse management was effectively squelched for about a decade. In a related development, Caltrans agreed in 1997 to discontinue use of herbicide on its right-of-way in Mendocino County and began using the California Conservation Corps to manually remove gorse. In 1999, State Parks acquired the Caspar Headlands, with gorse becoming better established following discontinuation of grazing.

Historically, gorse has fed wildfires frequently. Gorse produces heat so intense that firefighters cannot effectively battle flames that reach 30 feet in length, necessitating the use of aerial firefighting tactics. Cal Fire conservation camp crews have assisted in gorse removal, as well as contributing to the spread of gorse into the Jackson Demonstration State Forest. Regardless of the methods pursued, failure to maintain gorse removal sites has led to continual resurgences in local populations.

Caspar demographics have changed as the timber and fishing industries have declined. Subdivision of ranches and farms has led to fewer land managers and a greater proportion of part-time residents and retirees. Gorse thrives as much as ever in the abandoned fields and pastures.

MCWMA

In 2004 the newly-formed MCWMA held a community outreach meeting in Caspar – gorse was the highest priority due to the wildfire hazard. Common ground appears to be developing between those who oppose the use of herbicide and those who want to combat the gorse. Encouraged by the acceptance of the need for herbicide as part of an integrated pest management strategy for gorse, State Parks restarted treatment on Jughandle State Reserve infestation, which now exceeded what existed prior to the original control efforts of the 1980s.

The State Parks treatment started with mechanical uprooting and piling in early winter of 2006-7. Resprouts and seedlings were treated with Garlon. Dirt in the piles hampered burning. In fall 2009, gorse debris was incinerated in an air curtain burner, reducing smoke emissions near the highway. However, much effort was required to remove dirt from the debris, load the burner and empty it frequently. In the end, most of the piles were rebuilt to remove the dirt and burned in the open.

Meanwhile, the MCWMA received supplemental CDFA funding in 2008 for two gorse projects. The first project conducted surveys and treatment for outliers and created a buffer along the north side of Jefferson Way from the bluffs to the highway. The second project addressed the seven net-acre gorse infestation at the Caspar Waste Transfer Station, essentially duplicating the methods being implemented at Jughandle State Reserve, except using glyphosate rather than triclopyr to minimize the risk of leaching to nearby wells.

A resolution drafted by the MCWMA, Mendocino County Fire Safe Council and the Caspar Community, and narrowly passed by the Mendocino County Board of Supervisors included

- Approval of the use of herbicide on the Caspar Waste Transfer Station
- Permission for the WMA to insert leaflets on gorse into property tax statements

At present, the initial phase of the gorse removal at the Caspar Waste Transfer Station has been completed. In October 2008, mechanical pulling was carried out – dry, sandy soil contributed to clean burn piles, which were burnt in two days in April 2009. Monitoring indicated an initial density of germination/resprout of ten per square foot, dropping to one per square foot at the time of herbicide application in September 2009. Continuing follow-up will be performed through WMA Baseline funding and in-kind effort from the Ag Department. In a recent development, the Mendocino County Fire Safe Council has been granted federal funding for gorse treatment to reduce wildfire hazard.

Conclusions

An unproductive cyclic pattern of intense management and neglected follow-up has developed between gorse and humans. To break the cycle, we strive to

- Maintain communication that sustains the overarching support from the community for an integrated pest management approach that includes herbicides, at least on some properties
- Identify multiple benefits (hazardous fuel reduction, recreation, ecological sustainability, habitat restoration, ...) and tap into sources that target particular benefits
- Convince high-level management of the need for reliable long-term funding, and not start more than we can finish
- Accept multiple methods, but not accept bad methods. In the case of gorse

  Bad methods include prescribed burns (risky, encourages resprouting) and above ground removal without herbicide (resprouting with multiple stems)

  Acceptable methods may include herbicide (foliar, cut-stump, mechanical/herbicide), or not (manual, tilling, grazing, tarping, ...)
- Not despair: biocontrol agents undergoing approval (thrip, shoot moth) provide hope for a sustainable solution

Show Me the Money! Developing a Reimbursement Program with the Private Sector

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Abstract

Slender false brome (*Brachypodium sylvaticum*) is an invasive, perennial bunchgrass spreading through the redwood forests of Woodside, California. Slender false brome (SFB) has spread to over 10,000 acres in Oregon, forming dense stands and outcompeting native plants and tree seedlings (Institute for Applied Ecology). If left unchecked, SFB could eventually disrupt the native California redwood ecosystem. SFB has been designated a "noxious weed" in California.

The Midpeninsula Regional Open Space District (MROSD) began eliminating SFB from its preserves in 2004. In collaboration with landowners, MROSD developed a management program with a reimbursement plan to encourage

property owners to participate in the eradication of SFB on private property.

The MROSD SFB management program includes 1.) pretreatment surveys; 2.) herbicide application or manual control measures; and 3.) post-treatment restoration and monitoring. Upon completion of treatment, property owners are reimbursed by MROSD for treatment costs.

This paper discusses the challenges and positive aspects of developing a collaborative reimbursement program with private property owners. Some of the challenges encountered were differences of opinion regarding herbicide use, the amount of reimbursement and developing a plan applicable to multiple properties. Positive aspects have been the involvement of a diverse group of people who want to preserve the redwood forest and receipt of grant funding allowing MROSD to hire a coordinator for the program. By collaborating with private property owners, the District hopes to completely eradicate slender false brome in California.

Introduction

Slender false brome (SFB) was first discovered in 2004 in the Midpeninsula Regional Open Space District's (MROSD) Thornewood Open Space Preserve, which is dominated by coast redwood forest. SFB was also found in three other nearby preserves and neighboring private properties, but not elsewhere in California. The California SFB population is estimated to be approximately 100 acres. In 2006, SFB was designated a Class A noxious weed by the State of California.

MROSD developed a ten-year plan for management of SFB within its preserves and neighboring private properties. Since 2004, MROSD has successfully managed and reduced SFB on its public lands; however, SFB continued to thrive on neighboring private lands. Through public outreach, MROSD cultivated relationships with private property owners with SFB on their land. Aware of the potential impacts SFB could have on the redwood forest, property owners asked MROSD for assistance in managing SFB on their private lands.

The role MROSD, a public agency, would take in directing management of private property needed to be addressed thoughtfully. Some people were wary of a "government agency" telling them how to manage their land. Would MROSD staff or a contractor hired by MROSD conduct the work? The property owners suggested a reimbursement plan. This simplified MROSD's role in the treatment process and placed the liability for treatment with the property owners. A reimbursement plan also gave property owners the choice of how to treat SFB on their land.

In collaboration with private property owners MROSD developed a three-step program for treating SFB on private land and a reimbursement plan. Property owners participating in the program are reimbursed $350 per acre treated for SFB.

Methods

Woodside is located in San Mateo County between San Jose and San Francisco on the San Francisco Peninsula. Coast redwoods and mountainous terrain dominate this area. Two Woodside neighborhoods were approached for participation in the SFB management program. There are approximately 80 parcels over 100 acres of land.

In 2008 MROSD was awarded $15,000 by the National Fish and Wildlife Foundation. In March 2009 MROSD hired a SFB Coordinator and dedicated $25,000 to treating SFB on private land. With combined funds of $40,000 for treatment on private land, MROSD set out to identify and treat 50 acres twice in the 2009-2010 season.

Property owners participating in the SFB management program invite MROSD to survey their property. The number of acres of SFB determines the amount of reimbursement. Property owners treat the SFB, either themselves or with a contractor. After treatment, MROSD conducts a post-treatment survey. If the SFB has been successfully treated, either manually or with an herbicide, the property owner is reimbursed for the amount based on the number of acres treated.

Based on recommendations from a professional pest control operator familiar with herbicide treatment costs and the Natural Resources Conservation Service, MROSD proposed a flat reimbursement rate of $350/acre. The three-step process is applied parcel by parcel, working closely with each property owner. To complete the entire process involves extensive communication between MROSD and each property owner.

Results and Discussion

Developing a reimbursement formula applicable to multiple properties that had not been completely surveyed was challenging. The initial reimbursement formula offered less money and was more complicated ($150/acre or up to 50% of treatment cost, whichever was less). As MROSD received input from property owners about the amount of SFB on their lands, it became apparent that the reimbursement needed to be increased. MROSD more than doubled the reimbursement to $350/acre.

An important positive aspect of the program has been the property owners' acknowledgement of the impacts SFB may have on the redwood forest ecosystem and their willingness to participate. Once MROSD realized the potential for a large-scale invasion of the redwood forest by SFB, a public relations campaign to educate the public about the impacts of SFB was launched. SFB identification and information notices were posted in neighborhoods and preserves. Awareness of SFB and how it might impact something of value to the property owners (the redwood ecosystem where they live) appears to have been an important motivator for their participation and commitment to the program.

Another positive aspect has been the presence of several key people or allies in the neighborhoods. These property owners took ownership of the program and rallied their neighbors to participate. These people were instrumental in assisting MROSD in identifying property owners ready and willing to participate in the program and also those who would rather "wait and see" what happens this first year.

Herbicide "hesitancy" was a challenging aspect of the program. Property owners had the choice of how to treat SFB on their property. For large stands of SFB, herbicide application is the most cost and time efficient method of treatment. The initial projection for treatment of 50 acres of SFB predicted 98% would be sprayed and 2% would be manually treated (hand pulled). In actuality, of the total 51 acres treated, 32 acres (63%) have been sprayed and 19 acres (37%) have been manually treated. Initially, some property owners were hesitant to apply an herbicide for a variety of reasons (it would make their dog sick, belief in long-term environmental impacts; everything would be killed, etc.). Some property owners began manual treatment, however once treatment began they realized that manual treatment would be more costly than the reimbursement would cover. Some of these property owners then opted for a combination of the two treatment methods, hand pulling near their house and herbicide applied on the more remote areas of their property. Some property owners chose to manually treat their entire property even though it was more costly than the reimbursement would cover.

Property owners seemed inexperienced in hiring a contractor. Some took immediate action and began treatment right away, others appeared unsure of how to proceed. The uncertainty of how to proceed with hiring a contractor created a time lag between the initial survey and treatment, in some cases as much as six to eight weeks. Eventually one property owner contacted a contractor, creating a snowball effect of treatments as word spread through the neighborhood. By coordinating treatments twelve properties were treated in three weeks, a total of 28 acres of SFB.

The program will be evaluated moving into next season. The flat rate reimbursement formula was not always applicable to real conditions. As treatments began, it was observed there was a "base" cost to initiate treatment and that the reimbursement plan tended to favor larger parcels.

Since SFB has been in the area for several years, a seed bank is present in the soil. MROSD realizes it will not be possible to eradicate SFB with a single treatment or in a single season, a concept which is continually reinforced with the property owners. To motivate additional property owners to participate in the program will require on-going funding.

The first year of MROSD's slender false brome management program and reimbursement plan cultivated a cooperative collaboration between a public agency and private property owners. Twenty-one property owners are participating in the program. Since June 2009, 51 acres of SFB have been treated and $17,570.00 has been reimbursed for treatment costs with funding available to re-treat these acres by March 2010.

Money proved to be a motivating factor for private property owners to treat an invasive species on their land. Having a coordinator for the program has been essential for keeping the program on-track. With continued funding, MROSD intends to maintain this momentum to achieve the long-term goal of eradicating slender false brome in California.

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Working Together Against Weeds: Workshops, Materials and Best Management Practices to Prevent Invasive Species Spread Due to Land Management Operations

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Abstract

Unintentional spread of invasive species during management operations is often overlooked and may be a major driver of invasions in some management areas. Activities such as road maintenance, weed abatement, research activities, planting, seeding, hiking, backpacking, pack stock and other activities can all spread weeds. Finding workable solutions to these operational hazards is not easy and takes participation from all sectors of the organization. The Pacific West Region of the National Park Service has recently embarked on a multi-faceted effort to raise awareness of unintentional weed spread, cooperatively develop best management practices to limit spread and improve management operations with respect to invasive species management.

Introduction

There are numerous examples within the National Park Service (NPS) of unintentional spread of non-native invasive plant species through park operations. These examples include introduction of yellow starthistle into Yosemite Valley during road construction activities, movement of perennial pepperweed to an uninfested park site during invasive species control and restoration field work in the Santa Monica Mountains National Recreation Area and introduction of yellow starthistle from contaminated hay during post-fire rehabilitation projects at Whiskeytown National Recreation Area, to give just a few examples. These and similar incidents prompted the Pacific West Region of the NPS to ask whether we could take a comprehensive look at how park operations spread weeds and develop feasible best management practices for different park operations to limit this spread.

Although the program described here was developed by the NPS for use in park sites, it will have relevance to any land manager or agency that engages in operational activities such as campground maintenance, road maintenance, resource work, research, or any other field activities that have the potential to spread weeds. Many of the best management practices that we adopted and built upon for our program came from other agencies and groups such as the United States Forest Service and regional weed management area guidelines.

The goals of our program were three-fold. First, we wanted to develop a program that would raise awareness of the potential for operational activities to unintentionally spread weeds through use of contaminated materials or equipment or importation or movement of seeds, root stocks, or contaminated materials. This unintentional spread often involves work that is completely unrelated to resource management work but involves vehicles, people, stock, or equipment moving from an infested area to an uninfested area. The second goal of our working together against weeds program was to involve individuals working in a particular operational area in the identification of weed pathways and the construction of best management practices. It was our hypothesis that involvement of field workers in each operational area would result in higher buy-in from these constituents and in crafting best management practices that were actually feasible for the targeted user group and were thus more likely to be implemented. Finally, our third objective was to gather together, design and implement best management practices across all management operations to reduce the unintentional weed spread that occurs in parks (and other land management groups) as a result of operational activity.

Methods

Initially a small working group of resource managers from parks throughout the Pacific West Region was formed in 2007 to identify possible operations and pathways for weed spread within each operation. This working group spent approximately six months assembling materials on best management practices for each management operation from as many sources as possible including other agencies and non-profits. After this material was assembled, a three-day workshop was planned for Point Reyes National Seashore. For the workshop, we recruited staff from all of the different park operational groups from parks throughout the Pacific West Region. These operational groups included Interpretation and Education, Law Enforcement, Building and Utilities Maintenance, Trail Maintenance, Construction, Road Maintenance, Resource Management, Permits, Concessions, Horse Operations, Fire, Wilderness Operations and more! We identified five outcomes for our workshop:

1. Understand why non-native invasive species are a critical concern to park management
2. Identify how to better integrate prevention and control activities into operational activities
3. Enhance participants' knowledge of what plans/tools/programs/resources are available to staff and how they can best be delivered and used at individual parks
4. Discover ways to use our educational resources to increase awareness of and participation in weed control and prevention programs
5. Identify Best Management Practices (BMPs), roadblocks to implementation, and solutions to those roadblocks for Pacific West Region parks.

The workshop included general background information and presentations on why weeds are a problem for national parks, what we know about invasive species biology and spread, examples of unintentional weed spread and introductions to each operational area. Following this introductory material, the group then broke into working groups focusing on each operational area. Each working group was tasked with identifying pathways to unintentional weed introductions stemming from their operational activities, reviewing available BMPs that were assembled prior to the meeting, brainstorming new BMPs, identifying potential roadblocks to BMP implementation and identifying solutions to perceived roadblocks.

The initial working group took the materials generated from the workshop and condensed them into a set of reference materials including all of the assembled BMPs, introductory Powerpoint presentations and other reference materials. These materials were sent to all of the parks within the region and were also made available online.

The second phase of the project was initiated in 2009 and involved developing a one-day workshop around the materials developed by the earlier working group. This workshop was then offered as a service to parks throughout the Pacific West Region. During 2009, we had funding to put on four workshops. The first four parks to respond to the offer of a free workshop on preventing weed invasion were the recipient of this program. These parks were Joshua Tree National Park, Death Valley National Park, North Cascades National Park and Olympic National Park. During the summer and fall of 2009, a team of two to three NPS and USGS staff traveled to these parks and worked with the park staff to facilitate a workshop similar to the initial Point Reyes workshop held in 2007. The goals of these park-specific workshops were to:

1. Raise the level of awareness of weed problems within the park
2. Expose park staff to existing BMPs for various park operations
3. Conduct focused brainstorming sessions on pathways most relevant to individual parks with the goal of developing BMPs in partnership with the staff working in these particular operations
4. Leave the park with an overview of some future next steps that they might take to effectively combat their weed problems. The intention was that this mini-review could be used in fundraising efforts or to raise the awareness of park managers.

Workshops were attended by park staff from all operational divisions and were planned as a day-long focus on weed problems within the park. Resource management staff at the host park provided background material on the weeds of concern at the park hosting the workshop. In addition, local resource managers provided focus for the workshop facilitators on what the largest sources of operational weed spread were in that particular park. Brainstorming sessions for BMPs focused on these areas of greatest potential weed spread.

Results and Discussion

A total of five Working Together Against Weeds workshops have been presented. There has not been sufficient time since holding these workshops to evaluate how many parks developed and adopted best management practices as a result of this workshop. Nor is it possible to evaluate whether these workshops had significant impacts on park operations or reduced inadvertent weed spread from park operations. However, the workshops were well-attended by a diversity of park staff, were well-received based on workshop evaluations and served to raise the general level of weed awareness within each park.

Although each park we visited was different and had unique weed problems, several patterns emerged from our workshop visits. First, all parks appear to be seriously under-staffed when it comes to dealing with their weed problems. Each park typically had only one to a small handful of staff available to work on weed problems that were threatening the majority of ecosystem types found within each park. Second, many parks are feeling overwhelmed by their weed problems and are considering "giving up" on many problematic species. This decision about when to "give up" on species appears to be occurring in a vacuum of guidance or scientifically derived criteria for when to consider an invasive species problem a lost cause. Third, all of the parks that we visited appeared to be poised on the brink of disaster with respect to weed problems. Each had at least one if not several species that were present in the park at low densities but had the potential to majorly modify ecosystem functioning were they to spread beyond their initial small infestations.

The Southern Sierra Partnership

Hilary Dustin, Sequoia Riverlands Trust, Visalia, CA. hilary@sequoiariverlands.org

The Southern Sierra Partnership (SSP) is a new alliance of conservation and business organizations dedicated to rapid collaborative action to develop and implement climate action strategies, expand protection of sustainable human and natural communities, maintain ecosystem services and mobilize new funding and other resources for conservation in the southern Sierra Nevada.

The group's first major project is a landscape-level conservation planning effort that incorporates the most recent thinking on climate change adaptation and ecosystem services. Major outcomes will be a set of strategic actions designed to achieve significant conservation in the southern Sierra Nevada and Tehachapi Mountains, as well as planning tools to help others grapple with the uncertainties of climate change.

Hilary Dustin, Conservation Director at Sequoia Riverlands Trust, will review the SSP planning process to date, highlighting the group's assessment of the invasive plant threat, how it might interact with climate change and what to do about it. She'll be looking for feedback to take back to the planning team.

Aquatic Weed Management: A Survey of Techniques and Environmental Impacts 2001-Present

Michael Blankinship, Blankinship & Associates, Davis CA, mike@h2osci.com

The tools for aquatic weed management over the last decade have evolved to include new chemical, biological and mechanical control methodologies. Implementation of Integrated Pest Management (IPM) including Best Management Practices (BMPs) for the protection of sensitive ecological resources and water quality are more common than ten years ago. Although permitting requirements to perform aquatic weed abatement has been a cost burden to land owners, data gathered for permit compliance purposes suggests that for many abatement approaches, ecological resources are well protected. For some weed abatement techniques, however, an assessment of risk must be made so that cost/benefit scenarios can be clearly communicated to stakeholders and decision makers.

Refining Mechanical Removal Methods for the Eradication of *Spartina Densiflora* at Humboldt Bay National Wildlife Refuge

Andrea J. Pickart and Trevor Goodman, U.S. Fish and Wildlife Service, Humboldt Bay National Wildlife Refuge, Arcata, CA, Presenter's email: trevor_goodman@fws.gov*

Abstract

Over the past five years, staff at Humboldt Bay National Wildlife Refuge have developed a method for the mechanical removal of the invasive cordgrass, *Spartina densiflora*, using metal-bladed brushcutters. This method has been used successfully to remove *S. densiflora* from approximately 10 ha (25 ac) of salt marsh. All established Spartina is killed within two years, although seedlings continue to emerge from newly dispersed seeds (confirming the need for regional eradication). Revegetation methods were tested but native species recovery occurs rapidly without revegetation. The Action Plan for the West Coast Governors' Agreement on Ocean Health released in 2008 calls for eradication of all invasive Spartina from the West Coast by 2018. With the increased likelihood of available funding for regional eradication of *S. densiflora* in Humboldt County in mind, the Refuge staff established experimental plots in Summer 2008 to refine mechanical eradication techniques. These plots compare summer- vs. winter- initiated mowing in terms of efficiency (including labor needs, resprout density and seedling emergence) and the effectiveness of a higher mow height to suppress seed production and allow for phased implementation over a large area. We are also following algal colonization and succession, and native species recovery. Preliminary results indicate that the summer mow results in fewer initial resprouts but increased seedling emergence in the spring following mowing.

Introduction

The conversion of salt marsh to agricultural wetland in Humboldt Bay in the late 1800s and early 1900s reduced the acreage of salt marsh by about 90% from approximately 3,642 ha (9,000 acres) to 364 ha (900 acres). In addition to the reduction in available salt marsh, *Spartina densiflora*, an invasive cordgrass native to South America (Bortolus 2006), was introduced to the Humboldt Bay region in the ballast of ships transporting lumber to Chile in the mid-1800s. *S. densiflora*, which was not recognized as an invasive species until the 1980s (Spicher and Josselyn 1985), has since invaded the remaining salt marsh habitat in Humboldt Bay, Eel River and Mad River estuaries reducing native salt marsh to extremely low levels. Regional eradication is the only viable approach for the control of *S. densiflora*, because it readily propagates from tide-dispersed seed. Given the vocal community opposition to the use of herbicides in Humboldt County, the U.S. Fish and Wildlife Service has focused on the development of mechanical eradication methods.

Over the past five years, we have developed a method for the mechanical removal of the invasive cordgrass, *Spartina densiflora*, using metal-bladed brushcutters (Pickart 2008). This method has been used successfully to remove *S. densiflora* from approximately 10 ha (25 ac) of salt marsh. All established *S. densiflora* was killed within two years, although seedlings continue to emerge from newly dispersed seeds (confirming the need for regional eradication). Revegetation methods were tested but native species recovery occurs rapidly without revegetation.

If mechanical eradication over the three-estuary region were to take place, large areas would likely need to be phased and one strategy is to carry out less intense mowing in areas not yet scheduled for eradication in order to suppress seed production and therefore relieve propagule pressure in newly restored areas. The experiment described here was designed to measure the effectiveness of mowing to suppress seed production and the relative efficacy of mowing start times. We tested whether commencing mowing during partial winter dormancy compared with during summer reproduction affects the number of repeated treatments needed to kill *SS. densiflora*. In our previous large scale pilot project, we learned that seedlings emerged as a response to treatment (as a "flush") in the first spring after mowing (approximately March-May). Seedlings sometimes also emerged during the ensuing summer months. As yet, we have not identified whether seedlings are emerging from an ephemeral vs. a permanent seed bank. If the latter is true, even regional eradication will not preclude the need for continued treatment of seedlings after eradication of mature plants. As this adds to the cost of the treatments, we also examined whether timing of the mowing treatments affected seedling emergence.

Methods

The research was carried out within Humboldt Bay National Wildlife Refuge, on salt marshes located along the west shore of Mad River Slough, a northern extension of Humboldt Bay, which is located on the Northern California coast approximately 434 km (270 miles) north of San Francisco Bay. A total of 10 15m x 15m (225m^2) treatment areas were subjectively located and established in July 2008 within salt marsh in the Ma-le'l Dunes Unit; five within areas of low-medium *S. densiflora* cover (15-35%) and five in areas of high *S. densiflora* cover (>50%). Four treatments and a control were randomly assigned to treatment areas within each cover stratum:

1. Summer Eradication Mow (Begun August 2008). All *S. densiflora* was mowed to below the base of the plant with a metal blade brushcutter. The brushcutter is modified so that the blade can be angled towards the ground while spinning. After cutting away most of the leaves and stems, the blade is repeatedly pressed down onto the base of the plant, which results in the pulverization of the plant material. This action continues below the surface of the ground, until much of the shallow rhizome system is gone and a shallow depression is left behind. The treatment is repeated every five months until eradication of initial plants is accomplished. Wrack is raked and burned on site or removed as it can suppress native recovery if left in place (Pickart 1998). Emerging seedlings are also removed. The start date of this treatment is timed to coincide with reproduction, when stored carbohydrates are at a minimum.
2. Winter Eradication Mow (Start January 2009). This treatment is identical to 1. above, but is initiated in January, coinciding with the latter half of the partial winter dormancy period, when photosynthesis is reduced and stored carbohydrates somewhat depleted.
3. Early seed suppression (Start May 2009). At or before onset of flowering all S. densiflora

is mowed to a height of 20cm. This height approximately avoids impacting native species.

4. Late seed suppression (Start July 2008) at anthesis all S. densiflora is mowed to a height of 20cm
5. Control, no treatment

Within each treatment/control area five 15-m-long transects were established running north-south with 2.5-m between each transect. A total of 30 permanent plots, six along each transect, were placed subjectively to fall within areas with Spartina cover, but spaced with regard to systematic coverage of the overall treatment/control area. Measurements of percent cover by species, number of culms and (when appropriate) number of seedlings were collected in July/August 2008 prior to summer mow and late seed suppression treatment, in January 2009 prior to winter mow treatment, in April/May 2009 prior to early seed suppression treatment and in August/September 2009. Accuracy of measurements was increased through the use of a 50cm x 50cm gridded quadrat frames.

To determine the number of seeds that were prevented from maturing in late seed suppression areas, the height of all inflorescences was measured in the sample plots and this measurement was used to estimate seed production in the late suppression plots. This two-step process was necessary because inflorescences were mowed before seed maturation. Near the study area, we marked 60 plants in each density stratum near but not in the treatment areas. We measured the height of the inflorescence at the same time that measurements insides treatment areas were made. We then collected the 120 inflorescences after seed maturation and counted all seeds on each inflorescence. A regression equation was developed to predict the number of seeds that would have been produced on the mowed inflorescences.

Results

Timing of Mowing

By September 2009, summer mow treatments had received one initial and two follow up resprout treatments and the winter mow had received one initial and one follow up treatment. In both the dense and sparse-moderate treatment areas, mortality of Spartina was significantly higher ($p<.005$) in the summer mow treatment than in the winter mow treatment (Figure 1). Although the summer mow treatment had received an extra treatment, the first summer treatment mow resulted in a greater percent mortality than the first winter treatment mow and this trend was amplified by the second treatment.

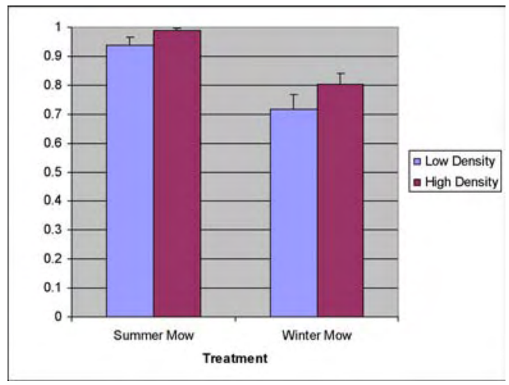

Figure 1

Proportion of dead culms in summer vs. winter mow treatment (mortality was calculated as the mean of the number of culms measured in the sample plots in Sept. 2009 as a proportion of the number measured prior to treatment).

Seed Suppression

Both the early (May) and late (July) seed suppression treatments resulted in close to 100% prevention (May) or mortality (July) of seeds. The seeds that had already formed and were knocked to the ground during mowing were periodically sampled to be sure that seeds actually died. The early treatment did not result in any secondary flowering. Based on the 120-inflorescence sample from outside treatment areas, the number of seeds on an inflorescence can be predicted ($R2 = .62$) based on the length of the inflorescence using the equation No. seeds = -99.9362+(16.754)length. There was no significant difference in the mean number of seeds/cm of inflorescence length between low and high density strata ($p<.05$).

Using this regression equation to estimate the potential seed set, an acre of dense Spartina would yield a staggering 49,367,712 seeds. Viability of seedset will be tested in the upcoming year.

Seedling emergence

Seedlings emerged in the summer mow areas at a rate of more than 7x that of the winter mow areas in low density Spartina areas (Figure 2a) and at a rate of more than 4 x in high density Spartina (Figure 2b). More seedlings emerged in high density Spartina than in low density Spartina regardless of treatment (Figure 2b).

Discussion and Conclusions

Although the experiment is not completed and will continue until 100% mortality of initial Spartina is achieved, interim results are informative. In terms of resprouts, the summer mow treatment was superior to the winter mow treatment. Mortality was swifter during initial treatments and greater by the end of the experiment in summer mow treatments. This could be explained by the greater stress experienced by plants during reproduction (when resources are concentrated on seed production) compared to partial winter dormancy. Summer mowing times are also logistically easier, since tides are lower for longer periods during daylight and the mowing substrate is therefore drier and easier to work in. Piles of wrack are dry enough to burn and do not need to be transported off site. However, the advantage conferred was offset by the much greater seedling emergence in summer-mowed plots. The summer mow areas were mowed five months earlier than the winter areas, allowing a much longer period for algal development prior to vascular plant seedling emergence or dormancy breaking. Prior monitoring has established that algal mats facilitate Spartina seedling emergence and/or germination on bare, mowed areas (Pickart 2008). Particularly in high density plots, a great deal of labor would be expended killing seedlings. However, there is currently no information on whether the *Spartina densiflora* seed bank is permanent (studies are in progress). If there is no persistent seed bank, then the use of mowing in combination with seed suppression of unmowed areas would eliminate seedling emergence. Under these circumstances, the summer mow date would prove substantially more efficient than winter mowing.

Acknowledgments

We would like to acknowledge the Joel Gerwein and California State Coastal Conservancy for their partial funding of and input into this project. The following individuals have assisted in planning, implementing, or in some way supporting the project: Luc Lagarde, Mike Swank, Jason Zito, Erik Jules, Andrea Craig and Jessi Graff.

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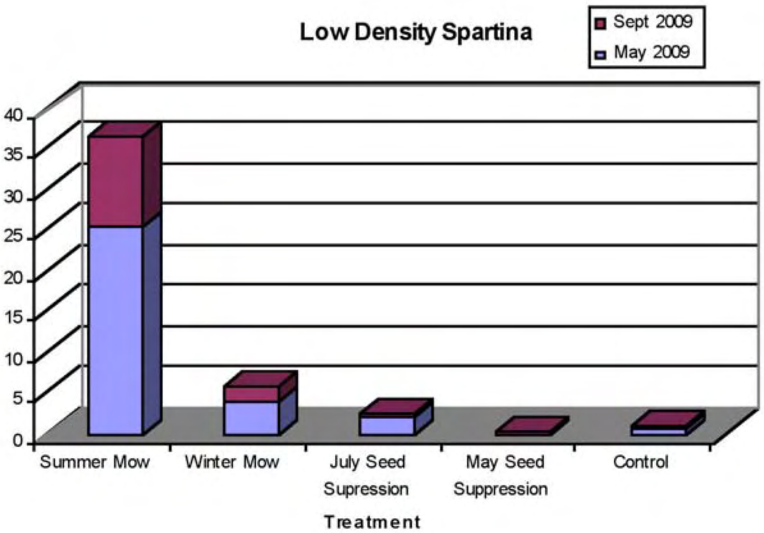
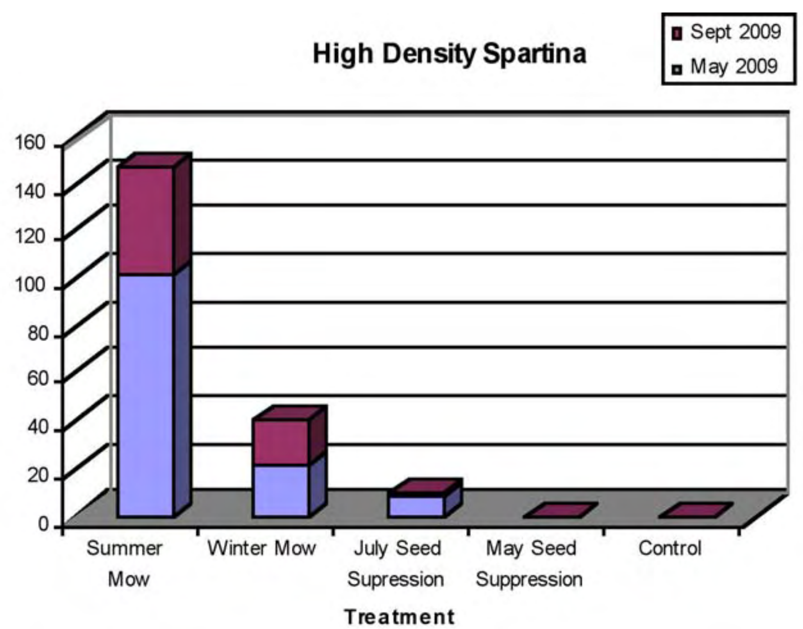


Figure 2a

Mean seedlings/.25 m^2 emerging following the onset of winter rains (May. 2009) and after the rainy season ended (Sept. 2009).

Figure 2a

Mean seedlings/.25 m^2 emerging following the onset of winter rains (May. 2009) and after the rainy season ended (Sept. 2009).



Making Room for Native Grasses: Physical Control of Coastal Weeds

Andrea Woolfolk, Kerstin Wasson and Nina D'Amore. Elkhorn Slough National Estuarine Research Reserve, Watsonville, CA. Presenter's email: amwoolfolk@gmail.com*

Abstract

Non-native species are the single greatest obstacle to restoring native grasslands in California. Generally, grassland restoration projects include not only removal of non-native species, but also the planting of native species. However, materials and labor for establishing native plants can be expensive and time-consuming, limiting the ability of land managers to restore large areas. Finding methods that allow for restoration of non-native dominated landscapes to native grasslands that do not include native planting efforts would greatly increase restoration capabilities. In two studies, we investigated the ability of weed removal alone to restore native grasses in areas near extant stands of native grasses and forbs.

In the first study, we hand pulled iceplant in the transition zone between salt marsh and a complex of grassland and coastal scrub. We compared plant composition before and after pulling. In the second study, we mowed four annual grassland plots for approximately five years and compared plant cover in these plots to unmowed controls at the end of the mowing regime. In the iceplant removal area, transects that had been dominated by iceplant before pulling were converted to an average of 85% native plant cover within months after pulling. In the mowing experiment, unmowed areas had significantly higher cover of non-native species than mowed plots and mowed plots showed trends of higher native grass cover and greater species richness. These studies suggest that, in some situations, short-term native grass restoration can be achieved without the planting of native species.

Introduction

Today, non-native species are the single greatest obstacle to restoring native grasslands in California (Stromberg et al. 2007). Restoration attempts often combine weed control with revegetation efforts. However, materials and labor for establishing native plants can be expensive and time-consuming, limiting the ability of land managers to restore large areas. Finding methods that allow for restoration of non-native dominated landscapes to native grasslands that do not include native planting efforts can greatly increase restoration capabilities. In two studies, we investigated the ability of weed removal alone to restore native grasses in areas near extant stands of native grasses and forbs.

Methods

The study sites are located in the Elkhorn Slough National Estuarine Research Reserve (ESNERR) adjacent to Elkhorn Slough, a large estuary in northern Monterey County.

Iceplant Removal

We examined the effects of iceplant removal on native plant cover. This study site is a transitional grassland situated between tidal salt marsh and coastal scrub. In 2006, we identified three iceplant (*Carpobrotus edulis*) patches, each approximately 50 m^2 in size, for removal. Before iceplant removal, in November 2006, we established three transects per iceplant patch. We assessed relative cover of plants in each transect by taking a point intercept every 50 cm. Any plant that touched a 0.5 cm diameter rod was counted as present at the intercept; in some cases multiple plants were encountered, so total cover exceeded 100%. Iceplant patches were removed in 2007 and 2008 by hand, by ESNERR staff and community volunteer groups. The permanent transects were revisited in July 2008 and plants were surveyed again, using the method listed above. Within-patch transects were treated subsamples and these data were averaged for each iceplant patch. Because this was a before-after survey, the samples were not independent, and we did not perform statistical analyses on these data.

Instead, we simply plotted the data and included standard error bars.

Mowing

We also examined the effects of multiple years of annual mowing on native grassland cover and species richness. This study site is located on grassy slopes above the estuary and was chosen because mowed trails contain several native grassland species, while adjacent unmowed fields appear to have fewer native plants. In February 2005, we set up four paired mowed/control plots, ranging in size from 77 m^2 to 150 m^2. Between 2005 and 2009, all four treatment plots were mowed once a year in February or March, using a tractor with an attached flail mower. Control plots were left unmowed. In June 2009 we established a single 10 m transect in each plot, haphazardly placed in approximately the middle of plot, running parallel to the slope. We assessed relative cover of plants in each transect by using the point intercept method, as described above. We also recorded all plant species present in a 1 meter swath along the transect. We used StatView to perform t-tests to compare relative cover and species richness between treatments.

Results

Iceplant Removal

Before hand pulling, all three patches had 100% iceplant cover, although salt grass (*Distichlis spicata*) and two other marsh plants (*Salicornia virginica* and *Frankenia salina*) could be found growing through the iceplant in many areas, as well. Immediately after removal, plots looked almost devoid of living plants. However, just three months after the last iceplant patch was removed in May 2008, native plant cover had increased from an average 49% (SE = ±9, n = 3) before pulling, to 85% (SE = ±6) after pulling. Most of this increase can be attributed to the increase of native saltgrass (Figure 1.). Native creeping wildrye (*Leymus triticoides*), rushes (*Juncus* spp) and exotic annuals (*Brassica nigra* and *Vulpia* spp) also appeared in low numbers along the upper edges of the pulled patches.

Mowing

Mowing significantly decreased the cover of non-natives (t-test, $P < 0.04$, Figure 2), appeared to encourage the growth of native perennial bunchgrasses, opened up a significant amount of bare ground (t-test, $P < 0.004$, Figure 3) and marginally increased species richness.

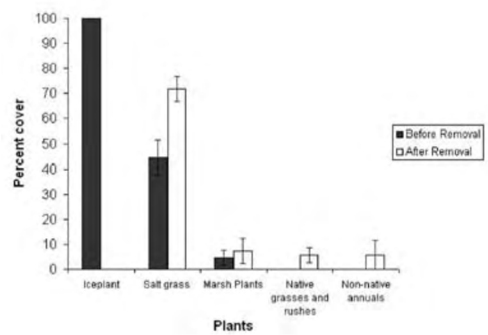


Figure 1

Mean (+/- SE, n=3) cover of plants in patches before iceplant removal and after.

Unmowed plots contained higher cover of non-native grasses including Harding grass (*Phalaris aquatica*) and wild oats (*Avena barbata*), although these were highly variable between plots. On the other hand, mowed plots had more, but not statistically significantly more, purple needle-

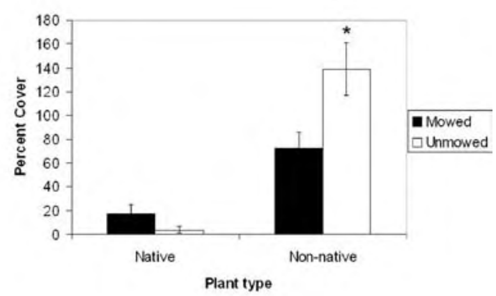


Figure 2

Mean (+/- SE, n=4) percent cover of native and non-native plant species in mowed and unmowed plots, June 2009.

* p <0.05.

grass (*Nassella pulchra*) and exotic forbs, including cat's ear (*Hypochaeris* sp.), filaree (*Erodium botrys*), and plantain (*Plantago lanceolata*) than unmowed plots. The native turfgrass, creeping wildrye (*Leymus triticoides*) was not positively

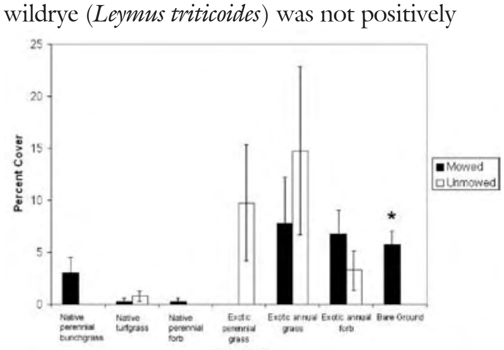


Figure 3

Mean (+/- SE, n=4) percent cover of plant groups in mowed and unmowed plots, June 2009. * p <0.01

affected by mowing, nor were native perennial forbs. Mowing treatments did not significantly affect the number of species relative to unmowed controls, but the data show a trend toward slightly increased plant species inside mowed areas. Mowed areas averaged 11.5 species per 1 m^2 swath (SE = ±1.6, n = 4), while unmowed areas averaged just 8 (SE = ±1.1, n = 4).

Discussion

This study indicates that weed removal alone may be enough to enhance native grassland species in areas where native plants are still found, either in low numbers intermixed with dominant weeds, or nearby in greater numbers. At the iceplant removal site, hand-pulling resulted in rapid recolonization by native saltgrass. However, it is quite possible that the site will require follow up work to maintain this high cover of natives. Mustard and vulpia had invaded the upland edge of the iceplant removal by the time of our survey; and D'Antonio (1993) reported that coastal California grassland can be quite vulnerable to iceplant invasion if disturbed by rodents. Nonetheless, the initial results are very promising.

Annual late-winter mowing decreased the cover of non-native plants, opened up bare space and appeared to make room for purple needlegrass, which was absent in unmowed transects. Although the cover of native species was not significantly different in mowed and unmowed plots, the average cover in mowed areas (> 17%) begins to approach ESNERR's best remnant coastal prairie patches, where natives make up on average 35% of the total plant cover and marks an improvement over unmowed controls (<4% native cover). Other studies have also noted the ability of mowing to shift California grasslands toward increased exotic annual forb cover and greater species richness (Maron and Jefferies 2001; Hayes and Holl 2003). While an increase in exotic forbs is not a desired outcome of grassland management, the accompanying decrease in overall non-native cover and increase in native bunchgrasses are making annual mowing in carefully selected areas a viable tool in enhancing native grassland communities. This study suggests that, in some situations, short-term native grass restoration can be achieved without the planting of native species.

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Controlling the Invasion of Noxious Rangeland Weeds into an Exotic-Dominated Grassland: Is There a Role for Native Grass Reseeding?

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Abstract

In California grasslands, noxious weeds (*Taeniatherum caput-medusae*, *Aegilops triuncialis*) remain active through late spring, after the long-term exotics (e.g. Avena, Bromus) have senesced. Native perennial grasses also have a later season phenology, suggesting that their restoration may competitively suppress noxious weeds. We planted two- and three- way mixtures of these three groups of species and exposed these plots to fall, spring, or no clipping. In the first year under unclipped conditions, long-term exotics greatly suppressed establishment of both noxious weeds and natives, while natives and noxious weeds had minimal impacts on each other. In the second year, the noxious weeds suppressed the native species and became more competitive with the long-term exotics. Spring clipping more than doubled the prevalence of noxious weeds and reduced native grasses and the long-term exotics. Fall clipping also increased noxious weeds, but without decreasing prevalence of other species.

Native grass restoration initially does not inhibit the weeds, but promotes them through the displacement of long-term exotics. It is possible that natives may become effective controllers of noxious weeds with increased establishment time. Of the species considered as potential competitors with goatgrass and medusahead, *Lolium multiflorum* may be the best candidate for competitively suppressing these noxious weeds.

Introduction

For the past two to three centuries, most of California's grasslands have been dominated by non-native species (e.g. Avena, Bromus species). While this historic invasion is a concern for many conservationists, these naturalized exotics have been important forage species for livestock. However, the more recent invasion of two noxious weeds, medusahead (*Taeniatherum caput-medusae*) and goatgrass (*Aegilops triuncialis*), has become one of the most pressing issues in rangeland management in California. The invasion of these two weeds can devastate diversity and decrease livestock productivity 40-80% due to decreases in the quantity and quality of forage (DiTomaso et al. 2007).

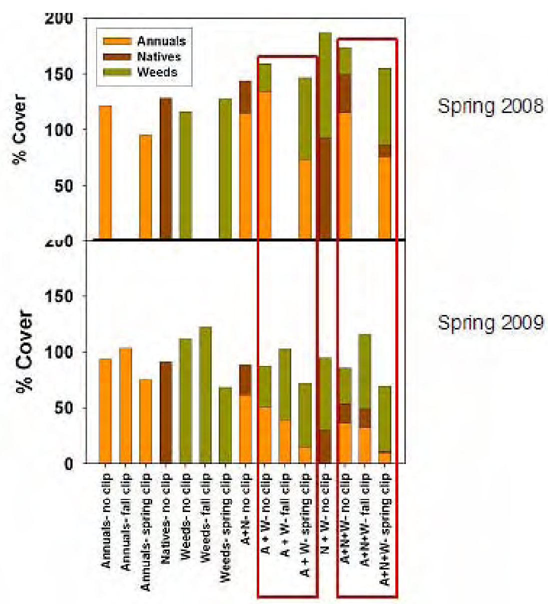

Figure 1

Percent cover of naturalized annuals, noxious weeds, and natives in spring 2008 (1a) and 2009 (1b) in unclipped, fall clipped and spring clipped plots.

During spring dry-down in these grasslands, when most of the naturalized annuals senesce, these two noxious weeds remain active for at least an additional four weeks. This difference in phenology has been used to time prescribed burns and intensive grazing to minimize new seed input from these weeds (DiTomaso et al. 2007). In this study, we consider how new weed control strategies may be derived from an understanding of the timing of peak growth and water and nutrient use of the noxious weeds vs. the naturalized annuals vs. native grasses.

1. Identify potential competitors based on overlapping phenology with weeds. Most of the naturalized annuals can't compete with noxious weeds during peak growth of the weeds, because at this time of the spring, naturalized annuals are senescing or already senesced. Many of the native perennial grasses have a similar timing of peak growth as the noxious weeds (Figure 2), suggesting that these native species may be able to compete with the noxious weeds.

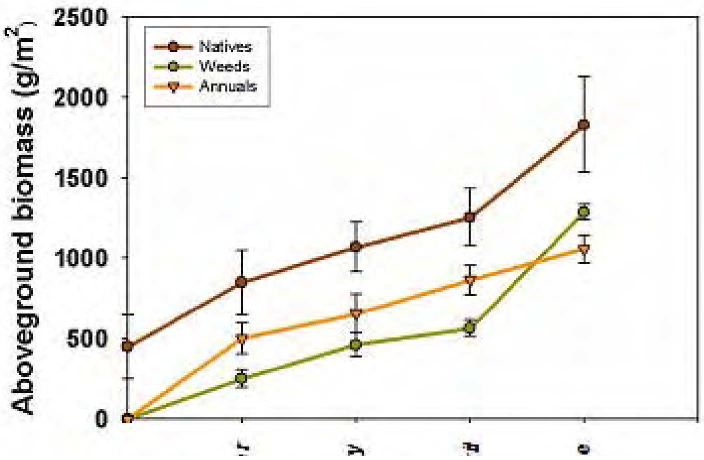

Figure 2

Timing of aboveground plant growth of natives, noxious weeds, and naturalized annuals.

2. Based on differences in phenology of peak resource uptake between desirable species (whether native or exotic) and weeds, predict how the timing of grazing impacts weed prevalence.

Methods

This research was conducted on the UC Davis campus research fields in California's Central Valley (38o32'44.58"N, 121o47'05.69"W, elevation 18m). This site has a Brentwood silty clay loam soil, a mean annual precipitation of 439 mm and a mean annual temperature of 16.7°C. In the fall of 2007, this site was lightly disked to remove all plant biomass. We then planted the following vegetation treatments into 2.25m^2 plots:

Naturalized annuals (annuals): exotics that have dominated for the past two to three centuries, including wild oats (*Avena fatua*), soft chess (*Bromus hordeaceus*), Italian ryegrass (*Lolium multiflorum*) and subclover (*Trifolium subterraneum*)

Noxious weeds (weeds): medusahead (*Taeniatherum caput-medusae*) and barbed goatgrass (*Aegilops triuncialis*)

Natives: California brome (*Bromus carinatus*), Blue wildrye (*Elymus glaucus*), Creeping wildrye (*Leymus triticoides*), Spanish clover (*Lotus purshianus*), Annual lupine (*Lupinus bicolor*), Purple needlegrass (*Nassella pulchra*), Pine bluegrass (*Poa secunda*) and Small fescue (*Vulpia microstachys*)

Annuals + Natives

Annuals + Weeds

Natives + Weeds

Annuals + Natives + Weeds

A subset of these plots were exposed to simulated grazing by clipping in the fall (twice in November and December) and spring (twice in mid-March and early-April). Each of these treatments was replicated 24 times and plots were planted in a randomized block design. An equal biomass of seeds was planted for all treatments and seeds were raked into the soil and germinated naturally with fall rains. Species composition was maintained by weeding out species that were not part of the original treatments for each plot. At the end of each growing season, species composition was determined by percent cover (modified Daubenmire) on the inner 1m^2 of each plot.

Results and Discussion

Using species with overlapping phenology to compete with weeds: In ungrazed conditions, all groups (natives, annuals, weeds) established fully on their own (Figure 1). In the first growing season, in mixtures, annuals greatly suppressed both natives and weeds, while weeds and natives had minimal impact on one another's prevalence (Figure 1a). These results are contrary to our expectation that weeds and natives would be most competitive with each other due to their overlapping phenology. Instead, these data suggest that for this first year, restoration of natives may enhance weeds, through the restoration activities removing most of the naturalized annual cover.

In the second year (Figure 1b), weeds increased their relative prevalence in all mixes, while annuals decreased their prevalence. The absolute cover of natives was the same in the first and second year when planted with annuals, but natives were strongly suppressed by weeds in the second year. There are two main factors that account for the different results seen in year 1 vs. year 2 of this experiment: annual variation in precipitation and annual differences in which species dominated within plant groups. In terms of precipitation, the first growing season (2007-8) had a very dry spring, with rains stopping by the end of February. This led to enough soil moisture to support the growth of each group grown alone, but in competition, the earlier-season annuals (Figure 2) likely usurped available moisture, leaving little for the natives and weeds. In contrast, in the second year of the experiment (2008-2009), there were some significant rains into June, leading to high amounts of moisture to support the growth of weeds.

Different results in the first and second year are also partly explained by differences in which species dominated within each group (Figure 3). In the first year, the annuals were dominated

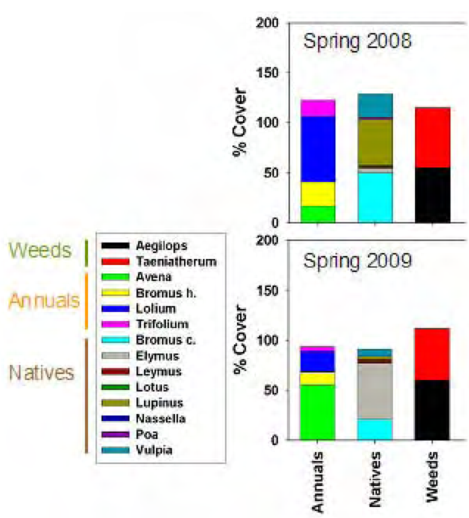

Figure 3

Plant species composition within plant groups in spring 2008 (top panel) and 2009 (bottom panel).

by Lolium, a late-season annual that has some phenological overlap with the weeds and later-season natives and thus is a likely competitor with these groups. In contrast, in the second year of the experiment, the annuals were dominated by Avena, which has an earlier phenology and is less likely to directly compete during the late-season growth spurt by weeds and natives. There was also a shift in species composition within the native community, with short-lived grasses and legumes dominating in the first year (which are likely to better compete with other fast-establishing annuals and weeds) and longer-lived perennial grasses dominating in the second year.

Overall, these results imply that rather than natives being promising competitors with the weeds, the weeds suppress the natives. However, Lolium, a later-season annual, may be an effective competitor with weeds due to phenological overlap (but it also seems to be an effective competitor with natives). There is still the potential for natives to contribute to long-term weed control, since the late-season perennial grasses only established in the second year of the experiment, so that their suppressive effects may become apparent in future years.

Effects of simulated grazing on competitive interactions

In both years of the experiment, spring clipping (mid-March, early-April) decreased the cover of annuals and natives, and more than doubled the prevalence of weeds (Figure 1). Medusahead strongly increased due to spring clipping, while goatgrass showed little change, or even decreased in abundance. Clipping in the early spring decreases the biomass of the naturalized annuals, thus leading to lower transpiration rates and a higher amount of soil moisture, which benefits the later-season weeds (Malmstrom, in preparation). Grazing later in the spring (just before weed seed maturity) is more likely to negatively impact weed prevalence (Cherr 2009). Fall clipping increased the prevalence of both goatgrass and medusahead, but did not decrease annuals or natives (Figure 1). We are currently investigating mechanisms to explain these patterns.

Overall, this study confirms the challenges of controlling noxious rangeland weeds, particularly under grazed conditions and highlights the importance of inter-annual variability in plant species interactions. However, under some conditions, naturalized exotic annuals strongly suppress these weeds, and further investigation into these dynamics may lead to promising management tools.

Literature Cited

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The Leading Edge of Weed Management: New Tools and Techniques

Can We Keep Invasive Plants at Bay by Restoring with Competitive Native Plants?

Elizabeth A. Leger, Department of Natural Resources and Environmental Science, University of Nevada, Reno, Reno, NV, eleger@cabnr.unr.edu

Changes in the species composition of biotic communities may alter patterns of natural selection occurring within them. Native perennial grass species in the Intermountain West are experiencing a shift in the composition of interspecific competitors from primarily perennial species to the exotic, annual grass *Bromus tectorum*. Thus traits that confer an advantage to perennial grasses in the presence of novel annual competitors may evolve in invaded communities. I will present evidence that native perennial grasses may be able adapt to the presence of cheatgrass, using examples from six different native Great Basin species collected from five separate cheatgrass invaded and cheatgrass uninvaded populations. In three of the five collection locations, species collected from invaded areas were significantly more competitive with *B. tectorum* than plants from uninvaded areas. Traits that appear to be adaptive in competition with cheatgrass are early fall green-up (in adult plants) and early seedling root growth (in seedlings). These traits were present in higher frequencies in populations growing with *B. tectorum* competitors.

While it is tempting to restore degraded areas to higher densities of natives (usually done by bringing in outside seed material), such actions may impede long-term adaptation to new conditions by arresting or reversing the direction of ongoing natural selection in the resident population. If hot spots of rapid evolutionary change can be identified within invaded systems, these areas should be managed to promote desirable change and could serve as possible sources of restoration material or reveal traits that should be prioritized during the development of restoration seed material.

From Backpacks to Jetpacks, Handpicks to Skidsteers: Leveraging Old Tools and New Techniques for Long-Term Restoration Success

Mark Heath, Shelterbelt Builders, Berkeley, CA. mark@shelterbeltbuilders.com

This talk will present case studies and demonstrations on the strategic use of tools and techniques for invasive plant management in challenging areas. I will review equipment and strategies from heavy construction, timber management and agriculture for their utility in habitat restoration projects, with special consideration given to how these strategies can also benefit worker health and safety. Finally, I will engage in a bit a dreaming about what future technologies may bring for those working in wildland weed management.

Beyond Weed Wrenches: New Tools and Techniques from Around the State

Joseph M. DiTomaso, Weed Science Program, Department of Plant Sciences, University of California, Davis, Davis, CA, jmditomaso@ucdavis.edu

The closing talk at this year's Symposium will focus on new tools and techniques to help weed workers and volunteers. Dr. Joe DiTomaso will give a round-up of new ideas to make your work more effective gleaned from what he and his staff have heard from land managers and researchers throughout the state. New tools will include an online weed identification tool that can be adapted for users' needs.

Discussion Group Notes

Control Methods Roundtable

These notes encompass the Control Methods groups on Thursday and Friday.

Thursday, October 8

Topic Leader – Joe DiTomaso, UC Davis

Facilitator – Mark Newhouser

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

Number Attending: 30

Start Time: 4:40pm

Joe DiTomaso started off the group with brief introductions. Introductions lasted 10 minutes. (4:50 pm)

Species of Interest

Giant reed (*Arundo donax*), knapweeds (*Centaurea* spp.), storksbill (*Erodium* spp.), *Euphorbia terracina*, perennial pepperweed (*Lepidium latifolium*), dalmation toadflax (*Linaria dalmatica*), tamarisk (*Tamarix* spp.), broom species, thistle species and a variety of grasses.

Attendee Employment Areas

Park service, private consultant, open space district, habitat authority, reserve/preserve manager, grower (Hedgerow Farms) and graduate student.

What is Matrix (rimsulfuron, Dupont) and what is it effective on?

It is a selective herbicide used to treat cheatgrass (Bromus tectorum) and can also be applied as a pre-emergent in the fall; needs soil contact to be effective. Rangeland uses.

May be effective as an early post-emergent herbicide

Hedgerow Farms – effective on medusahead (T*aeniatherum caput-medusae*), applied three weeks post-rain, at a rate of 4oz/acre

- In spring medusaehead was effected but natives "looked good" including; lupines, poppies, brodiaea, and oaks
- Not as effective on goatgrass (*Aegilops triuncialis*)

Joe DiTomaso – tested on sagebrush community. Effective on clovers and invasive grasses applied with a boom sprayer over 50 acre plots. Generally does not affect native species, including native perennial grasses.

Are pesticide Laws and Regulations widely known and followed?

Nelroy Jackson commented that laws and regulations need more attention within herbicide applicators and regulators.

Court Case – Idaho

Oust (Dupont, Matrix family of herbicides) was applied to a burn area. Light soils were blown into a potato/sugar beet field. Agricultural damage occurred and case was brought against applicator. Grower won case. The moral of the story is be aware of your surroundings and try to foresee environmental disturbances which may increase herbicide motility.

2,4-Dichlorophenoxyacetic acid (2,4-D) – review regulations

Imazapyr – very easy to get off label. As well as being illegal this is a waste of money. To minimize over-application the drizzle, whip or roller application methods can be used. These methods apply large droplets and are effective at keeping the herbicide on the target species with little dispersal by wind.

How do you control medusahead?

- Disking reduces thatch and buries seeds which may increase seed life, as well it exposes buried seeds. Seedbank lasts at least two years. Disking also degrades soil structure and is not advised.
- To remove thatch – burn if appropriate
- Mowing has been shown to control medusahead. Time mowing to occur just prior to seed maturity.

How do you control European beachgrass (Ammophila arenaria)?

- Habitat (Imazapyr) has 95% successful control. A mix of glyphosate and Habitat (2% and 1%, respectively) has been shown to be a very effective mix that interrupts two enzyme systems within protein synthesis. Native colonization was not shown to be effected by treatment. Sandy soils may minimize long-term effects of Habitat soil activity through leaching, but short-term leaching may increase root uptake and plant kill. Negative effects can be seen three or more years post imazapyr application.

Joe DiTomaso – You may see long-term effects from Habitat as dead plants degrade into the soil and re-mobilize the herbicide. Kill zone is the term used to define the soil area with active herbicide compounds able to kill plants.

Nelroy Jackson – The glyphosate/Imazapyr mix increases herbicide mobility and efficacy and also minimizes negative effects by decreasing the total Imazapyr applied per acre.

How do you control tamarisk?

- A mix of glyphosate and Imazapyr gives a good kill.

How do I control giant reed within red-legged frog (Rana aurora draytonii) habitat?

- Regulations are really restrictive, no wicking applicators.
- Stem injection – glyphosate

  Easy to get off-label, 5 mL per stem.

  Need to apply to most/all stems to see effective control
- Solarization has been shown to be effective with excellent results on an organic farm.
- Cut stump is effective on small patches and not effective on large patches. Application timing is important.

What are some ways to increase public awareness and sympathy for herbicide use?

- Trailhead signs or displays describing the study site
- Change display based upon seasonal applications
- Regular weed removals involving the public which engage volunteers and non-profit groups

Ballistic Technology (paintball herbicide application) – James Leary

- High volunteer satisfaction!
- The method can be done from the ground (foliar or stem) or by helicopter (canopy) and accesses difficult terrain – "weed sniping".
- There is zero risk of drift and can be applied from 100ft of the target plant, at 300ft/sec.
- Fountain grass (*Pennisetum setaceum*) may not rupture on impact due to the plant architecture.
- Lethal dose – 30 to 40 units (paintballs) per plant. This was an estimate for tree applications. Single shots = sub-lethal doses, diminishes native risk.
- Application rate is under legal label rate.
- Since paintballs apply the herbicide within a capsule this is considered a new use of the product.

Adjourn Meeting (5:35 pm)

Friday, October 9

Topic Leader: Joe DiTomaso. UC Davis

Facilitator: Mike Kelly

Note taker: Kristin Weathers, UC Riverside

Attendees:Paul Aigner,David Thomson, James Leary, Charlie de la Rosa, John Knapp, Bill Winans, Amelia Swenson Judy Johnson, Peter Warner, Tanya Meyer, Martin Hutten, Chuck Synold, John Anderson, Joanna Clines, GiGi Hurst, JP Marié, David Minnesang, Ellen Gartside, Ginger Bradshaw, Ken Moore

Attendee Interest

Species: barb goatgrass, yellow starthistle, tamarisk, perennial pepperweed, purple loosestrife, St. Johnswort, medusahead, brooms, Erodium, Arundo, fennel, figs

Methods/tools: interested in alternatives to basal bark treatment, specialty products, grazing

Herbicide Discussion

- New herbicide, Matrix, (rimsulfuron) as discussed in first discussion session.

Does Matrix tank mix well?

Joe DiTomaso: I have not used in a tank mix, do not know.

Attendee: We use clethodim to take out medusahead, rye grass, goat grass. Does not seem to hurt bunchgrasses, can take two years.

Joe DiTomaso: It doesn't work well on big grasses. How expensive is it?

Attendee: About $40/acre.

Attendee: We are also using fluazifop. It seems to work better early.

Mike Kelly: Fluazifop also picks up Erodium. It does kill lilies, knocks back or kills outright.

Erodium

Joe DiTomaso inquired if attendees were having long term problems with Erodium. Many attendees said they did and there was a group consensus on revisiting listing Erodium.

Mike Kelly: Telar works on Erodium

John Anderson: We use Milestone on Erodium,

Joe DiTomaso has not had much luck with Milestone on Erodium.

Killing palms by drilling holes and injecting low rates of glyphosate.

Mike Kelly: Need to shave up tree with chainsaw, then drill in. Regulators accept because they like the standing dead for birds (owls will use palms).

Fan palms only need a single hole, 1/2 oz glyphosate into middle will kill. Dilute with water to get better movement into the plant (dilute 50%).

Use plastic tubing to squirt herbicide inside.

Phoenix palms are harder, there have three vascular bundles and you need to drill into all three to kill the palm.

Need large drill bit. Uses 5/16 construction drill bits (belt hanging tool bit).

Technique also works on eucalyptus. Uses auger bits.

Anyone have issues with agave species becoming invasive (Agave americana)

Joe DiTomaso: That is native.

Attendee: Maybe I have the wrong species. We have hundreds of plants on a dry, south-facing slope.

I have been experimenting with using saltwater to control weeds

Joe DiTomaso: That is the oldest herbicide in the world.

Mike Kelly: What is it controlling?

Attendee: Seems to have worked on fennel, hemlock, white horehound (there is a poster in poster session), knocks back perennial pepperweed,

Joe DiTomaso: But it is not systemic.

Attendee: Regulators said pumping salt water onto land is not regulated.

Mike Kelly: Doug Gibson used it on Arundo, but I do not remember the results.

Attendee: It doesn't generally inhibit natives (working in saline environments), but some of the less salt tolerant natives did die.

Does anyone have experience using aminopyralid on blackberry?

Attendee: I work in Yosemite National Park and can only use aminopyralid or glyphosate. Cannot use triclopyr. Yosemite has individual park regulations. Until a couple years ago, we couldn't use any herbicide.

I sprayed Milestone (aminopyralid at seven oz/ac) on blackberry.

Treatments were started late May (early green berry stage), this knocked it back, but late season (July) treatments did not work as well. Full sun plants were more susceptible than shade plants.

We have 80 canopy acres of blackberry. Going up into drier sites.

In the fall it is easy to kill, but it is a logistical hassle; so I am trying to increase the window with Milestone treatments. For now I am using glyphosate.

Joe DiTomaso: I think Milestone is not good on woody species, but every so often someone tells me it works.

Controlling Perennial Pepperweed

Joe DiTomaso: I've had inconsistent results with Telar – it does not work well in higher organic matter soils.

Mike Kelly: Lepidium is the one weed I don't have a handle on. I get good top kill and second year control, but it comes roaring back in the third year, so I am not killing the root.

I have tried combining Telar with Garlon 4, thinks they were going at too high a rate, so trying lesser rates.

Trying goats. Following goats with spraying is giving the best result. Natives (*Baccharis*) came roaring back.

Still finding roots at five m (young study)

Attendee: I have tried imazypyr in aquatic habitat, effective at higher rates, but less selective.

Mike Kelly: Some concern with residual and movement so not using it as much

Attendee: I've had better results with Garlon 3A, but not Garlon 4

Attendee: I've had more resprouting with Garlon than Roundup

Joe DiTomaso has not had good luck with triclopyr on pepperweed.

It is important to hit lower weeds. Tony Svejcar study - showed best control at full bud stage or later. Mark Renz, one of Joe's students, found that did not get good translocation to root at later growth stages. Joe mowed and found that only 10% re-flowered but all put down basal leaves. They treated over the top of basal leaves and get good control. The mowing did not matter with Telar, but did with glyphosate.

Using goats: $15,000/acre to use goats. In San Diego have to bring in goats from northern California – comes with a herder 24 hours. Goats like manzanita and willows. Goats can be trained to eat one plant. (leafy spurge was the example)

Attendee: What surfactants do you use with telar?

Joe DiTomaso: R-11 is the surfactant of choice. Have found it has a higher safety factor than listed on the label.

Joanna Clines: I have three or four times as much Klamathweed/St. Johnswort (*Hypericum perforatum*) as five years ago. We have bugs, but I am still concerned. Have not used herbicide

Mike Kelly: Garlon and glyphosate work on *H. canariensis*

Joanna Clines: We introduced bugs, then had a burn come through.This increased the plants then the bugs wiped it out. Now population has increased again. Think bugs are selective on high nitrogen content plant.

Joe DiTomaso: I wonder if you are seeing an increase because bugs don't like the low nitrogen plants?

Joanna Clines: I am also concerned because the bugs may eat natives. Mike Pitcairn says the bugs will work and we are just seeing the lag. I am concerned about sitting tight.

Joe DiTomaso: Plants can get resistant to other management techniques besides herbicides.

Joanna Clines: I would like to get researchers involved. It looks like bugs are stripping one patch, but leaving a huge amount of others.

Peter Warner thinks he is also seeing an increase in Klamath weed in NW and does see bugs. He does not think the bugs are killing the plants.

Joanna Clines is seeing dense patches precluding natives, different from what she has seen in the past.

Joe DiTomaso: Thinks bugs are present, so that is not problem (bugs travel good distance).

Joanna Clines thinks quantity not sufficient.

Mike Kelly has added pre-emergence to his tool box

Landmark XP (Oust and sulfometuron) added glyphosate for just emerging plants. It did not affect coastal sage scrub shrubs that were already established, or Distichilis. Seeded a year later. Killing oats and mustard and was pleased with results

Joe DiTomaso says must be careful with perennial grasses.

Mike Kelly: Nassella was OK.

Joe DiTomaso: You must revegetate if you use pre-emergence compounds.

Mike Kelly: I have used oyzalin (Surflan) close to vernal pools for grasses, not as effective on mustard. Stays on top of soil. Is effective on goat grass. Not registered in non-crop.

John Anderson: We are using a product called Outlook. That is registered for sod farms. Knocks out rattail fescue. Not registered non-crop. Also use Vista has no effect on grasses, sedges and rushes. Safe on adults and juveniles. Gets bristly oxtongue, Erodium, marestail. 24 hour residual.

John Knapp: Have you heard of Milestone working on fennel?

Joe DiTomaso: It works best on certain families: sunflower, legume, Polygonaceae. It should work at high rate, but I have had never used it.

Attendee: has anyone tried aminopyralid as preemergent for cheatgrass?

Joe DiTomaso is setting up experiment.

Attendee: I am experimenting with velvetgrass with low rate of glyphosate, but getting too much overspray.

Mike Kelly: You can buy a nozzle that has plastic cone, to prevent overspray

Attendee: We have a large acreage.

John Anderson: You can get air induction nozzles put out by TeeJet (Teejet.com) that prevent overspray.

Adjourn.

Mapping Points, Lines, or Polygons: Which Data Representation Works Best for My Project?

Leader: Jason Casanova

Panelists: John Knapp, Ingrid Hogle, Steve Schoenig, and Jason Giessow

Note taker: Lynn Sweet

Attendees: Tara Athan, Korinne Belle, Shane Barrow, Jason Casanova, David Chang, Ellen Gartside, Jason Giessow, Ingrid Hogle, Laura Jones, John Knapp, Erin McDermott, Lizo Meyer, Steve Schoenig, Lynn Sweet, Tom Warner

This year's mapping workgroup session will examine the ever-present question, "What data representation(s) should one use when collecting data for an invasive plant monitoring/management program?" Inquiries that frequently arise in mapping include: What data representation works best in my situation? What are the pros and cons of each representation? In what situations should I use multiple representations? Are there guidelines or resources available to assist me in choosing a method? After I select a representation to implement, what BMPs (Best Mapping Practices) or data collection techniques apply to that particular representation?

A panel of experts will present a brief synopsis of their monitoring program, representations they use frequently, and BMPs they utilize to collect those representations. A majority of the meeting will be an open discussion where participants will be able to share their own experiences (pros and cons) with data representations. Those participants that are new to mapping will have the opportunity to ask questions relative to their own situations and use the group Q&A session as a "help desk" to jump start their own mapping efforts.

Jason Casanova gave an introduction to mapping. Most attendees seemed to need pointers on a current mapping project, rather than input on planning a new one. Panelists gave an overview of mapping projects they work on and the thought process behind selecting an appropriate data representation.

Giessow: Polygons work best for his projects because he deals with a limited amount of species and many of them are large form (easily identifiable from aerial photographs). He maps stands by digitizing directly on a tablet PC. This method works well for generating control cost estimates for grants. Working top-down you can look at the overall cost for a watershed and scheduling of work. One example where polygons did not work for him was Artichoke thistle. Polygon data was collected initially. After control, he chose to collect point data rather than mapping polygons with excessively small cover classes (e.g. 0.01%). Nowadays he also takes points when tracking Arundo retreatments.

Hogle: In the Spartina mapping project, they use points, lines and polygons depending on what is most efficient. Lines are useful when the infestation is walkable and linear. The line is walked and recorded, and width beyond the line is estimated and attached to the data along with a cover class. One problem is that it can be hard to update older data with new information. You can update the whole feature as "treated" or "untreated." If you go back to an older spot but the feature doesn't match the ground, it can be hard to decide whether to expand the existing feature to cover it, make a new feature, etc. You can get into splitting hairs.

They use ArcPad and now have a method of either copying and pasting a feature or changing it to a line, etc. The decision about what to do depends on the scale of mapping and the overall goal.

A new system they also use is grid-based. They estimate cover percent within cells of a grid. Although this is not their preferred method, it works for non-straightforward distributions of plants.

Knapp: They map multiple species. On Catalina, they mapped 72 species. This involved hiking, 600 miles of transects in about a year. They used points and lines for infestations along roads and drains (with width and density). Following this, they used a helicopter to survey 55 weeds on Santa Cruz, all from the air, due to the difficult terrain. They used lines and points to get baseline data and collected area and density for later treatment. A variety of methods works best for treatment and/or monitoring for the future. They reduced damage and disturbance using the helicopter and improve visual accuracy.

General Considerations and Hints

Giessow: Large plants in the field can be seen on aerial photographs and on the former Microsoft GoLive site. You can get two foot oblique data from all cardinal directions. Polygons on the ground may be 15% off but it is a start for seeing distribution landscape-scale. They also have a Brassica project along roads. The goal was a Rapid Watershed Inventory for a WMA.

Hogle: Cover class is important. They have a system for taking both cover class and "treatment cover" class. This is due to the non-equivalence between how much ground is covered by a plant (percent) and how much area needs to be sprayed. For example, an area on the ground with five feet diameter may have only 20% of the ground physically covered by a weed, but since the cover extends evenly over the whole five-foot circle, that is 100% treatment class. To find the treatment area, multiply the gross area (e.g. five feet) by the treatment cover class (100%) to get area. This is essential for knowing how much herbicide to return with, for example. Information about information is important.

What scale is your project? Consider breaking up the area into squares, record what is present there and then map obvious problem areas as points also within that grid. That way you have your bases covered. Where you have mapped and where you did not cover is also important, or else no one will know if the weed was absent there or just not mapped.

Schoenig: The California Weed Mapping Handbook is a resource for mappers: http://cain.ice.ucdavis.edu/weedhandbook . (The California Weed Mapping Handbook is the product of collaboration between CDFA, CDFG, CalEPPC, USFS and CAIN).

Consider in your project which weeds you would like to include. 700 weeds is a lot, so consider doing a few, as in Cal-IPC-listed plants, or things you would like to eradicate. Also, how extensive is your infestation?

Documentation and Absence Data

Knapp: Also important for mappers is a breadcrumb trail (the GPS can record where you went in addition to the plant location points you record). This gives a better record of thoroughness. Also you can accurately say what land was covered for a report or grant. It also helps to make sure the workers don't overlap.

Hogle: The boundary of the inventoried area as well as absence data within that area is not trivial. Though it can be time-consuming; it is important. Have your data-gatherers draw where they went that day on a map or aerial photo. Have them record what they saw and didn't see. If you're mapping using binoculars, you need to use another method, since breadcrumbs track where you actually went. This is where you can use a software or printed "Tracking Grid" to check off areas that are done. Check them off as "done" or "not done" at the end of the day.

Q & A Group Session

In Yosemite, they have problems with getting enough satellites visible to have good precision. They would like polygons to derive area of infestation. How do you decide between a polygon and a point, when the desired resolution is to map a 10m-patch.

Hogle: In training workers, it's helpful for them to picture their car and use this as a known gauge of size and distance.

Knapp: People can estimate better looking downward than upward.

Giessow: It can be a problem of reference, for instance, the moon on a horizon looks bigger than it does high in the sky. This is not a problem of atmospheric distortion; it's literally a problem with perspective and reference that makes it appear bigger when it is not.

Suggestion: Take a large number of points in a reference spot and have the GPS average them to give one accurate point with which to gauge accuracy of data as a whole on that survey.

Hogle: What if your estimates are off? Do a power analysis to see how much error is tolerable for your project. Put simply, if you're looking for a significant 5% reduction, 5% error is too much. If you're looking for a 70% reduction, that error may be OK. You can also just flag the perimeter of the patch physically to see changes.

Schoenig: Ask yourself if you need this level of accuracy. What accuracy do you need to reach your goals? You could instead pick certain patches as monitoring patches and measure them with higher accuracy, as representative of the whole project. Then just map the others. Basically do a subset of areas well and use those to gauge progress. But the question remains, do you need this level of precision?

Knapp: Sometimes you have to track eradication success and then after that, surveillance mode may be less effort-intense.

Giessow: Sometimes higher resolution is used to map, for example, endangered plants, like orchids. In this case you might GPS each orchid. If it's bigger, you could use a grid or just a polygon. Sometimes you can spend as much effort in mapping as you would to kill the weeds.

If I'm mapping invasive grass in redwoods in a program to reimburse homeowners for control of slender false brome, their reimbursement is based on acreage. What mapping methods would work best to help me track treatment in this case?

Hogle: You can use "Treatment Percent" in this case. What percent of what area do you have to physically apply herbicide to?

Giessow: You could also track treatment area using the capacity of the backpack sprayer and the rate. However, in this case, retreatments of the same area might show less "treatment area" because less herbicide might be used on a large area of scattered resprouts. In general, this might work given accuracy of ID and little overspray.

Schoenig: In our CDFA program, we've eradicated 5,000 populations of 1 to 1000 acres. We calculated our net acreage controlled based on usage. If eradication is the goal, sometimes you can break up a large unit into smaller parts.

Giessow: It also helps to know how much chemical you've applied over how much land (especially important when using imazipyr). Eradication can take a long time. When contractors are bidding on a project, they need to know the size of the trees (i.e. diameter and breast height, area, size and age class).

Hogle: Acreage should be explicitly defined. Net acres or patches?

Giessow: Some numbers aren't accurate, so it's important to record percent cover and overall area of a stand. Remember that vegetation mapping is not the same protocol as invasive species mapping

Knapp: On Santa Cruz we used 100 feet between populations to delineate separate populations. This was just based on utility. This is how we differentiated patches. "Patch differentiation" is the threshold distance at which you consider two patches to be unique. This number can vary by project, goal, species, etc., but needs to be explicitly defined.

Audience Comment: Another issue is turnover in projects. Sometimes you inherit data, so metadata and other relevant information is important to document.

Knapp: On projects sometimes you change your protocol in stages. For instance, you take point data to map the overall distribution of the populations to guide staff. Then when you go back to actually treat, you do a thorough survey and take down more detailed information.

Hogle: Points are simpler to maintain than polygons. You can use a tablet to re-digitize in the field with good imagery. Sometimes you can redraw the polygons on aerials. Another issue is that tablets may be heavy and dim in the field.

Research Needs for Invasive Plant Management and Ecology

Discussion leader: Dr. Edith Allen, UC Riverside

Notetaker: Heather Schneider, UC Riverside & Cal-IPC Student Chapter

Attendees: Sara Jo Dickens, Chelsea Carey, Ellen Cypher, Erin Degenstein, Claudia Allen, Ginger Bradshaw, Peter Warner, Seta Cherbajian, Kristina Schierenbeck, Christiana Conser, Charles Blair, Jeremiah Mann, Gavin Archbald

A discussion on invasive plant research needs for managers researchers, and regulators. Cal-IPC recently developed a framework on research needs for invasive plant management and ecology, including regulatory and social issues (www.cal-ipc.or/ip/research/researchneeds.php). However, managers are continually faced with local, site-specific issues for invasive species control and new species are introduced with unknown ecological characteristics. This discussion is an opportunity to help set the invasive species management research agenda for California. We will also discuss finding and developing sources of funding to carry out the research.

An executive summary of the Cal-IPC Research Needs Assessment was distributed to all attendees and discussions were based off of these topics, as well as introduced topics from attendees.

The importance of determining which pathways of entry are facilitating introductions to California

- The USDA Q-37 guidelines address this issue.
- The USA doesn't always do a good job of patrolling what comes into the country as far as biological pollution.
- People are aware of the problems with possible modes of introduction, but there is little work on which sources are the most problematic or how to change it.
- Sources of aquatic invasions are especially important and should be evaluated more quantitatively, aside from the aquarium trade and ballasts, which are known methods of entry.
- Moderator: Is anyone here trying to work on pathways of introduction?

    No one in the group is working on pathways currently.

    One problem with studying pathways is that right now, the problem is addressed piecemeal at different levels and by a range of different agencies.

    There is also a problem of scale. Should we address pathways at the country, state, or local scale? Where is the starting point?

    The "Leading Edge Program" is another initiative helping with this issue.

  There is a problem of moving propagules. Even some species native to one part of California become invasive in other areas of the state. *Lupinus arboreus* is one example.

  Most often, people move propagules.

  It is also important to consider geographical and cultural pathways. There has not been much work done on this.

  There is a lot of knowledge on this topic, but it isn't always shared appropriately and used to make management plans.

  There is a need for greater information sharing.

- Cleaning up waterways is a good way to address aquatic invasions.
- Illegal dumping of garden debris is a source of introductions. There should be more strict regulation and enforcement of illegal dumping and refuse disposal.
- The interface between social and biological research is a black box that needs to be explored because both play a role in invasion.
- We don't really know how often animals are sources of invasive dispersal.
- There is a paradox of endangered species being invasive elsewhere.
- Climate and geographic matching models evaluate potential spread of invasives. The CLIMEX model is one example of this. However, climates do not always match and there is work going on to study this and help improve models.
- Invasive spread has not become a predictable science.

Genetics

Moderator: What issues should we consider dealing with genetics?

Kristina Schierenbeck – "because we don't know about so many things, like hybridization of brooms, blackberries, etc., we shouldn't plant anything that has a native congener because we don't know what can hybridize and become invasive. *Spartina anglica* is an example of hybridization and this needs more research and political attention."

The nursery industry develops 'sterile' cultivars, but we don't really know how stable they are and the definition of 'sterile' is questionable.

We still don't understand what makes plants become invasive.

Weed Lists

This is a major focus of Cal-IPC.

Weed lists are always incomplete and require constant updates.

Aquatic weed lists need more attention.

The Invasive Species Council of California Advisory Committee will make a state weed list. Of course, it will be incomplete and always require updating, but it will be a valuable list.

Two attendees, Kristina Schierenbeck and Christiana Conser, are both on the advisory committee and are looking for good criteria for weed lists.

Attendee: How do you define a weed?

How do you define native and non-native?

Plants can be exotic invasives, native invasives, exotic weeds, or native weeds. These words can mean many things.

There are a lot of grey areas in classification and nomenclature for weeds.

The terminology often depends on the person (ie farmer vs. land manager). For example, Amsinckia is a weedy native that ranchers often dislike, but restorationists like it because it can compete with invasives.

It is important to make sure that invasive plants are no longer planted for any purpose.

Attendee: What do the 'younger' people in the room find the most interesting in terms of research?

Ginger Bradshaw: There is a statistical model for tamarisk habitat, but it's very hard to determine how, why and when a plant will invade. How do we know when a model is good enough? It's important to compare models with data and validate them extensively.

Sara Jo Dickens: The effects of exotic invasion on soils and soil microbes as it applies to restoration is an interesting subject. This information will help tell us what needs to be done in regards to soil to ensure effective restoration, if anything. This links into the need for more study on ecosystem effects of invasions.

Chelsea Carey: Soil manipulations for restoration is a new area of research for invasive ecology that is interesting. She also worked on mulching versus tilling effects and nitrogen mining with *Rhamnus cathartica* in Chicago. They used corn as a cover crop for three years to remove nitrogen and then restore natives. It's important to manage for self-sustaining habitats.

Charles Blair: Effects of nitrogen on serpentine soils. Heather Schneider gave a talk on nitrogen deposition effects and invasives in the desert today.

It would be interesting to study the effects of yellow star thistle on soil microbes. This area is understudied, although some Centaurea species are thought to be allelopathic.

More research is needed on soil invertebrates.

Effects of treatment of invasives on soil and ecosystem effects of fire, herbicide, weeding, etc. should be studied.

One issue with restoration is that people often try to restore with a late successional stage when it is inappropriate for the state of the soil.

Soil nitrogen does decrease over time, but weeds often come up in the mean time. Mulch and sugar treatments to reduce soil nitrogen can't be used on a large scale. More research is needed to determine proper courses of action for decreasing soil nitrogen.

When non-native and invasive species are used for economic purposes, it gives them value and more people will plant them. Are there cases where the benefits outweigh the costs?

Land managers have to apply general principles from research to specific sites and test them. We need more site and species-specific information.

Cal-IPC and other organizations should steer us away from biofuels because it is still burning carbon.

- There is an issue of new vs. old carbon.
- Are biofuels really carbon neutral because of carbon uptake by plants?
- We know pumping CO_2 into soil doesn't work.
- Onsite biofuel machines could take out existing Arundo and harvest the biomass to make biofuel without the need for planting fields of biofuel crops.
- Algal biofuel uses a harvest smokestack of CO_2 that is pumped into the algal lagoon.

Attendee: If we aren't killing all of the weeds in areas where they are treated, how do we know we're not making the weeds stronger?

- Treating weeds aboveground is not genetically altering them.
- Even if all of the weeds aren't killed, treatment decreases the ability to create propagules and giving natives a better chance of survival.
- Herbicide resistance could become an issue, but there is no resistance to hand-pulling and solarization probably won't select for stronger plants.

More research on outreaching to kids is becoming increasingly important. More people now live in cities than anywhere else and children are not as connected to nature as they used to be.

Educating the public about management practices helps keep them informed and supportive of invasive control efforts.

Social issues should be better studied.

There is a need to develop more specific, less general knowledge via site-specific studies.

There are many areas that need continued research. The need for collaboration between social and biological research was highlighted, as well as involving the general public in exotic control efforts. Many of the areas touched on in the discussion have been studied to some degree and dissemination of information is important. Soils are an understudied topic in the invasion ecology literature. Invasive plant ecology is a multifaceted, unpredictable science with numerous opportunities for continued research.

The Unique Challenges of Long-Term Follow-Up Monitoring

Moderator: Sue Hubbard (Bureau of Land Management)

Attendees: Mike Bell (UC Riverside), Athena Demetry (Sequoia National Park), Rich Thiel (Sequoia National Park), Tessa Christensen (Pinnacles National Monument), Russell Jones (Pinnacles National Monument), Ken Moore (Wildlands Restoration Team)

Topics Discussed:

- Intoduction/definitions
- What should your goal be?
- When do you decide to stop working a site?
- Keeping Staff/Volunteers Trained and Motivated for Long Term Monitoring
- Should you plant natives after removing invasive weeds?
- How do you keep track of sites
- New tools

Introduction/definitions

Eradication – completely remove the species, including seedbank, from an area where there is no seed source that can reinfest the area is the definition I am using but many other definitions exist.

Eliminate – remove the species from your property, but species exists in the surrounding area close enough that the area could be infested.

Control – limit the spread of the invasion.

When do you know you are in follow up stage?: Maybe less area needs to be treated in following years or else the same area is covered, but the exotics are less dense. Also may be dealing with younger stages of the plant.

It is important to determine what the goal is of your treatment. It isn't always to eradicate or eliminate.

Athena: Bull thistle is hard to locally eradicate. If you miss one plant, it can disseminate 10,000 seeds which restocks the seedbank.

Questions whether it is a better management strategy to persist at one population and knock it back completely, or else to move on to a new population the following year. Therefore cycling through populations to keep each at a low level.

What should your goal be?

Russell: It is important to develop goals for individual programs.

Rich: Another option is using a technique such as grazing mowing or spraying for a year or two. This reduces weeds for a few years, before they come back and force you to repeat. This technique only gives you control.

Ken: Bull thistle has a short invasive cycle. It has a very high initial disturbance, but is naturally thinned to manageable levels in about seven years. It's important to know each species invasion cycle and plan management accordingly.

Sue: At my sites a lot of iceplant comes in after fire or other disturbance. I am not going for eradication but if I stop the above ground expression the shrubs will grow back and likely remain there for many years before the iceplant gets another chance to grow back.

When do you decide to stop working a site?

Russell: To ensure that the seedbank has completely grown out, three years appears to be the standard time to go without seeing a plant at a site before saying it is gone.

Sue: I have two small yellow starthistle sites that had no recruitment for two years, but found plants in the third year. Spotted knapweed has a seedbank that may survive for up to 18 years. Is three years sufficient to be sure a plant has gone?

Ken: Knowing the seed cycle of a plant is key to planning management. The seedbank life can be variable. Broom was not seen in a restored area for 15 years and then a Monterey Pine fell down and the broom came back anew.

Russell: Need to initially monitor a site to know the full extent of the invasion, then hit it hard.

Some species are harder to hit back then others, such as bull thistle. You miss a few each year, because they are still in rosette form while others are already seeding.

Rich: Bull thistle likes moisture and Sequoia NP has been getting extra monsoonal moisture recently. Changing climate can change propensity to invasion.

Keeping staff/volunteers trained and motivated for long-term monitoring

Russell: When plants have rosettes and mature plants at the same time it increases the time required for proper management. Must revisit the site multiple times and bring tools to attack at multiple phases. Will often have to cut off seeding heads.

Ken: It gets harder to manage an exotic population each year. The community shifts from non-native dominated to native dominated. It is harder for volunteers to find individual plants when they are hidden in a sea of natives. This makes new volunteers less valuable, because they aren't familiar with the location and aren't tuned into what the plant looks like in real life. It's also difficult because there may only be a few individuals and each may be at a different stage of progression. This phase can be more mentally exhaustive than physically.

Sue: When you don't see things in the field, it can be hard to stay focused, even if you are invested in the project. This makes it even harder for new staff volunteers to stay focused since they haven't invested as much of their energy into the project.

Russell: It's important to keep trained volunteers for a long period of time to be successful. Then have newer volunteers complete simpler tasks to stay productive and motivated.

Athena: Conceptually, it would be great to have volunteers adopt a watershed. That way they could continue working in the same area, and take pride in it. This is hard, because it's hard to find people who will commit long term. But if you can, people will feel ownership over the land and may stay focused on the overall goal.

Russell: Pinnacles is looking to start an adopt-a-campsite. Have a local boy scout or community group adopt a site and see the progression over time. This can suffer from the same problems as keeping long term volunteers because of turnover in groups.

Repeat volunteers want to see that their work matters. They put a long term investment into the land and have a sense of ownership in it.

Ken: It's hard to keep long term volunteers because their lives change. When you can find long term volunteers that are committed, they want to eradicate a site.

If a group has large turnover, initial removal is a great project, but loss of information over time makes it harder to follow-up and keep an effective group working in less invaded areas.

His experience has determined that over 50% of people who volunteer never come back.

Everyone loves seeing visible, dramatic progress, so it is harder to keep people around for long term care because not much changes from year to year.

Ideally we could create a traveling entity that moves to different areas. Kind of a watchdog group for an area that will constantly search and destroy invasives. It would be like a Federal Exotic Plant Management Team, but for public and private land. A team of experts.

Rich: Best case scenario would be unlimited funds and housing. Then success would be obtainable.

Long term follow-up is tedious work, and new volunteers can get frustrated. By taking them to mass infestations, it will give them an idea of what the land used to look like.

Sue: I find that in order to locate scattered/hidden plants, I need to work when they are in bloom and most visible. This means I am often pushing the time when they go to seed. This often results in having to clip seed heads at the same time I am killing the plant. This is time consuming but better than missing the plant because you were at the site too early to see it.

Some invasives such as Jubata grass will grow a new seed head two weeks after the old one has been clipped off.

Athena: When dealing with long term projects sometimes it turns into perpetual maintenance and gardening. It is important to get the idea out to staff that this project might not end. It is especially important for upper management to understand the true timetable of the project. Not the ideal time table.

Ken: It's important to get management to buy into perpetual maintenance. While it doesn't look sexy, it is necessary sometimes. After 20 years, some sites are actually complete. When dealing with French Broom, there still may be seeds in the seedbank, but since the perennial vegetation grows in, the seeds don't germinate, although, local disturbance could cause new germination. If monitoring has completely stopped, this could lead to a secondary invasion. As Paula noted in an earlier talk, rodents at some sites can completely turn over the soil in just 15 years.

Sue: Removing mature jubata grass makes for a visible change for visitors, but must get people to understand that the job is not done.

Russell: It's also important to make sure people understand that following up on these sites is still the same project. If you forgo monitoring you are wasting the early work done on a site, and therefore wasting money. It's a Lose-Lose situation because the invasives come back, and the original volunteers are demoralized.

Should you plant natives after removing invasive weeds?

Ken: It's a two sided coin. Some revegetation that is properly maintained gives the site an advantage, although maintenance is tough. Most of the time a lot of money is spent but not much success is attained. Different sites need different types of restoration, so it will be very site specific.

Athena: With Reed Canary Grass, you need to revegetate afterwards, because too much thatch is present on the ground for natural vegetation to grow.

Ken: Generally speaking, a natural seedbank is there and it will come up in time.

Sue: We had a disturbed site with poor soil that was covered with yellow star thistle that I thought would need revegetation. However there was a little nassella growing at the edge of the site and it is moving into the rest of the site on its own. I no longer think revegetation will be necessary.

How do you keep track of sites?

Sue: I have over 100 klamath weed sites. I print out a list of all sites to visit each year and attach maps on 8.5/11" paper behind that. It is small enough to be manageable in the field and I can write notes on it as I go.

Ken: Uses PDA with GPS capabilities. It has 7.5" quads loaded into it, and he is capable of making notes on the screen. It is small and very handy.

This has historically been a problem with getting a GPS reading in some locations, but the new chips are much better. The SIRF3 chip can get readings in steep, forested terrain. If you are having problems, you can look at satellite positions online, and then plan your field day by the angle of the canyon and the location of the satellites.

Ken: Often past people have left a physical description of the site. This is hard to pass to future workers, and the site may undergo changes over time.

It is a good idea to have satellite photos of the site, so that you can see landmarks around the area. If you need to make exact measurements as far as which trees invasives are near, then you should bring flagging, and mark the trees. It is important to bring it back each year, just incase the orginal flagging is falling apart.

Even return visits by the same person aren't going to be exact. When you have a lot of sites, some plants might be missed. It is important though, to make sure that your data logging allows someone else to reproduce your assessment in following years. Have a site specific description associated with the GPS points. Under which bush is the population? What type of tree is it growing near?

Athena: Keeping good data can also help motivate employees/volunteers. Having a map of the change in exotic population over time can provide proof of effectiveness.

New tools?

Ken: I am looking at using model radio controlled model planes with cameras and then fly over the area with GPS attached to find new invasives.

In Hawaii, they are using herbicide in paintballs and then using them to attack plants. With this technology, you could create war games against invasives.

There was a poster being displayed of an Iphone application that allows the user to record the location of an invasive plant when they find it, and it uploads the location to a main database. Users can score points for uploading the most locations.

Saharan mustard (*Brassica tournefortii*)

Leader: Matthew Brooks, USGS, Steven Ostoja

Notetaker: Gina Darin

Attendees: Mary Dellavalle, Ellen Cypher, Jay Goldsmith, Doug Gettinger, Sue Weis, Cindy Burrascano, Frank Aulgur, Matt Yurko, Jason Giessow, Shannon Lucas, Bob Case, Larry Klaasen, John Ekhoff, Steve Hoskinson, Kathryn Kramer

New information on ecology, impacts and control of Saharan mustard (powerpoint):

1. Ecology
   a. Saharan mustard arrived in 1920s in Coachella Valley.
   b. Why does it do so well in the desert?
      i. R. Marushia's dissertation, UC Riverside, shows that Saharan mustard has an early and rapid phenology, which takes advantage of desert conditions.
      ii. Other desert species bolt, flower and set seed later, when there isn't much water left over.
   c. Seed production – moderately sized plants can produce up to 16,000 seeds per plant, which is in the ballpark of many weedy species, but far more than local natives
   d. Grows well in sandy soils or disturbed areas caused by fire, OHV's or roads.
   e. Spread

i. Spread of Saharan mustard away from a paved highway in Chemechuevi Valley in Spring 1999 was as far as 1500 m away, and studied again in 2009 as far as 6500 m away.

ii. One vector of spread observed is dust devils, carrying plants miles into intact dessert.

iii. Kangaroo rats cache seeds, but often don't recover them, which may explain clusters of seedlings

iv. Siliques are explosively dehiscent, so managers may actually spread it if they manage too late.

f. 2005 spring (300% annual rainfall) Saharan mustard was found in significant stands on mid-slopes and mountains, not just in sandy washes, which shows it's not limited to sandy washes and roadsides = wakeup call.

g. How far north on east side? Up 395 in Manzanar, so it's moving into the Great Basin

h. How long are seeds viable? No studies, but black mustards seeds can be viable for eight years.

i. Density of Saharan mustard vs. natives during wet year was a negative relationship between density of Saharan mustard vs. natives may be evidence of competition. During dry year a positive relationship between the two, maybe all plants trying to survive and likely environmental conditions determine densities (R. Marushia dissertation). Comment – 1st germinating individuals shaded out others. If use percent cover instead of density may get another picture.

2. Impacts

a. High biomass production in 2005 may promote fire spread, but not likely as much as annual grasses. Likely doesn't cause the fires, but where it occurs (along roadside) is coincident with where fire starts (along roadside).

b. Creosote over story may get more fire damage due to the Saharan mustard.

3. Control

a. Previous control efforts limited to mechanical (hand-pull, hoe), bag and haul off site.

i. Concerns with this approach

1. Seeds may ripen even after plant is pulled, so need to manage seed bank.

2. Rosette vs bolting. Hard to pull basal rosette, so wait to bolting.

3. Hand pulling can be shown to reduce Saharan mustard with successive years of control, but it's labor intensive, especially in rocky substrates and under brush.

4. Also, mechanical methods creates soil disturbance.

b. Current strategies

i. Site led approaches – rare plant sites

1. Lake Mead NRA – sandy soil endemic species project, repetitive control with mechanical methods multiple times per year since 2003

ii. Habitat protection – dunes

1.) Mojave NP – prevent establishment in Kelso Dunes by pushing back Saharan mustard using herbicides 2,4-D and Dicamba spot spray post emergence

iii. Vector sites – corridors

1.) Joshua Tree NP - road corridors, trying to reduce amount of seed production

iv. Prioritize isolated patches

v. Keep it out of uninfested areas

c. Chemical control

i. Little herbicide testing has been done on Saharan mustard in natural areas, but mustards are on many labels.

ii. 2, 4-D Dicamba has some soil residual activity, so if there's a rain and germination, may get more control, whereas glyphosate gives same results as hand-pulling.

iii. Discussed USGS preliminary results of ongoing control experiments presented by Steven Ostoja (see powerpoint). Spring 2010 sampling at all 2009 treatments needed before conclusions can be drawn.

Careers in Invasive Species Management

Leaders: Cal-IPC Student Chapter

1 hour formal discussion with panelists followed by 30 minutes of open questions

Please state your name, education level, employer and job title

Doug Gibson (DG): San Elijo Lagoon Conservancy, Master's Degree, Environmental Science

Julie Horenstein (JH): California Department of Fish and Game, Master's Degree

Henry Gonzalez (HG): County Agricultural Commissioner- BS in Ag. Science and MA in Public Administration

Edith Allen (EA): Cooperative extension/University Professor- PhD Restoration Ecology

Fletcher Linton (FL): US Forest Service Forest Botanist – Masters in science.

What is a typical starting salary for your job? What is the average pay for a seasonal employee? We do not need to know your personal salary, but ballpark numbers.

DG: Interns unpaid. Internship is 20hrs/week for one year, $12-15K. Education director 40-65K, Masters – yr long program

JH: Student assistant = $11-15/hr (HR Office), www.spb.ca.gov Working for state, Environmental Scientist = $40-$60K/yr, Staff $60-$70K/yr. Agency salaries are generally less than private sector but the trade off is that agency jobs generally have better benefit packages, stability and pensions.

HG: Office of Agriculture, salaries vary by county. Generally Ag. Aid requires high school degree and starts $11-$15/hr, Prof Ag. Inspect biologist requires a four year degree and has three levels of a career series: Deputy Ag Commissioner $45-$90K/yr, Assistant for Ag. Commissioner $95-$120K/yr, Ag. Commissioner $120-$175K/yr. The later are also political positions.

EA: Extension – Land grant Universities have cooperative extension advisors and specialists, county level starts $50-$100k/yr, campus cooperative extension is the same as professor salary $60-$130K/yr. High job security.

FL: FS, BLM, Park Service: Bachelors degree can get you in as a Student Career Employee Program Intern. This places you in botany and invasive species positions. Full time positions are hard to get, but biologist starts at $30-$40K/yr and works up from there. Seasonal employment is common for 20 something's running May-Oct $15-$25K. Often you must be willing to move to climb the ladder to crew leader or Program management. At this level biologist/botanists are considered GS-11 and make $50-$75K/yr which is the highest position in the field. Once you are in a unit, you can move up to admin, but then your field time greatly diminishes. High job security at the permanent fulltime position level.

Describe a typical day at your job? What are the best and worst parts of your job and what were you not expecting to deal with?

DG: Monday surf, Wednesday yoga… keep your people happy and your retention will be high. We pay high for a non-profit. You get some field time, interact with agencies, lots of meetings. Being able to manage people is critical and the skills of conflict resolution are important. I am responsible for bringing in grants which is stressful, but love the job.

JH: Department of Fish and Game I spend time on many things: regional office, field, state HQ = policy and administrative programs, mapping programs and regulations. In general, the regional offices are more field-focused and the state headquarters are more policy and administration-oriented. No day is the same and I like that, but a fair amount of time is spent on budget and department-wide or branch planning or reporting tasks (i.e. talking and writing about the work rather than actually doing the work). Daily tasks could include: reviewing grant proposals as part of the CA Weed Management Area Advisory

Committee or participating in a conference call to develop regulation changes for private fish stocking (a potential vector for spreading invasive species). I also prepare reports describing how grant money has been spent on projects and manage grant budgets. Some time is also spent responding to inquiries about invasive species from consultants, staff, students and the public. Over time, our program works on everything from early detection to response to outreach. Unfortunately there are only two people in DFG doing statewide invasive species work, so we are spread too thin, which can be frustrating. There are other statewide invasive species management programs, but they are either focused on one or two species, or a particular part of the state's infrastructure (e.g., water delivery, roads).

HG: Diversity of projects prevents me from being bored. Laws and regulations to protect agriculture. Maintain level playing field for farmers (business), quarantines (federal, state, etc.), enforcement, monitoring, inspection. Detection of invasive populations, i.e., pheromone traps to capture flying pests (gypsy moth), to detect populations, at which time, we move from detection to an eradication project. I conduct surveys of suspect and known population locations, which sometimes requires mountain biking or hiking (nice perk). Some challenging parts of the job involve public intersections and education. We also do containment, suppression and export inspections, too, as well as pesticide regulation – permits and monitoring is a big part of the job. I investigate complaints and enforce permit laws for pesticide use and conduct nursery inspections. As well, we do weights and measures work to check produce quality and correct quantities. I conduct citrus monitoring. There are a lot of programs and diversity. We figure out how to use the county budget to implement regulations at the county and local level (Secretary of Agriculture). Some revenues come from grower certification fees. I do get some choice in what to focus on as a policy setter.

EA: My day consists mainly of research and outreach: 2/3 research, 1/3 outreach. I conduct basic and applied research. I communicate with stakeholders about natural resource issues (parks, state, federal). Often the job requires fielding phone calls from public. I submit many grants to fund research to Feds., NSF,, EPA,… Much work is done with county advisors. Outreach requirements can be in the form of workshops a few times a year for habitat conservation, planning, or for the public. I receive many invitations to talk (one or two per month). The job is intellectually stimulating and I can to some extent choose my projects. The down side is the administrative stuff like meetings. Overall the job is very enjoyable.

FL: A typical day is not typical with 50:50 field:office. I might be supervising treatments in the field, writing budgets and reporting accomplishments, writing NEPA reports or ensuring we are following NEPA regulations. Much of the office work includes mapping, data base management and meetings. In the field I conduct surveys, monitor and train crews, and implement safe practice protocol. I'm happy if I get back to my truck and get home safe at the end of the day. I also work on rare plant habitat improvements, fire, timber and invasive species issues (detection, containment, eradication, and prioritization). Outreach/education is also a part of the job giving talks to the public, i.e., CNPS and guided walks. It is a great way to inspire people. I enjoy that I work in the field because it feels like a vacation. The worst part of the job is the big planning process for management can be long and dense. I didn't expect to be required to do accounting and budgeting. I would advise getting accounting classes.

What skills should one acquire to increase hire-ability? Are there certification courses required? Should we take special classes while we're still in school? What are some good ways to gain skills not received in school that will be requested in applications?

DG: Know how to do everything (ha-ha). First, accounting is important as you will need to work with and write budgets and grants. It is very different from the university grant competition. You will need data management skills, GIS, IT (web skills very valuable), Photoshop and people/conflict resolution skills. I notice that many students come out of college deficient in land management education. I am in the process of creating a land management certification to help fill the gap in qualified people to manage lands skills to help parks do analysis to acquire land, budget to keep in perpetuity. Also you need hands-on skills such as being able to build a fence. I typically see that many graduate students are too focused. You need multiple experiences; practicality is very important. Volunteering is a great way to get experience and get your foot in the door. Many of my employees were volunteers first and made themselves too valuable to let go so I had to hire them.

JH: Know that the biota will probably be different from where you came from, so you will need the ability to find the information you don't already possess. Showing the ability and motivation to "get up to speed" on the local biota and issues is important. A research background is important because you could be reviewing research reports or proposals. Experience in designing and analyzing research or monitoring projects can help you critically evaluate these documents. Classes in environmental law (CEQA, NEPA, CESA, FESA, or water quality laws) would be helpful. Taking a job in environmental consulting can be a crash course in environmental law and sometimes they will even pay for classes.

The ability to write clearly and concisely, using correct syntax, grammar and punctuation is very important. In some cases you may be writing for a less technically inclined audience and, in some cases, you will be writing for your peers. To increase these skills, you can take a business writing class (some are available on-line). You want to have a good attitude (the "I can do it" attitude) and contribute in such a way that makes you indispensable. Be independently driven and responsible. A number of peers have told me that they have found training in project planning or project management very useful, especially for complex projects involving multiple people or groups.

HG: Ag commissioner needs help in the summer months looking for disease. This requires walking of fields looking for symptoms. These seasonal positions can get you on the job training. Insect trappers are also a good place to start. Being bilingual will be a major plus as employees often need to talk with people native to Mexico (many dialects). Other important items to make your application stand out include computer skills, university success and attitude. Attitude is not on the application and can't be taught on the job, you just need a "go to" attitude. Once you have the job, be on time and follow directions. As for requirements, you need a four year degree and to take the state exam. In this field, training never stops, you will always be required and offered to take continuing education classes.

EA: County cooperative extension requires a Master's although we are seeing many PhDs now applying for this position. The university level requires a PhD. The degree can be in any area of natural resources, restoration, forestry, fisheries, aquatic… All systems have invasive species to study and deal with. Skills or training of importance include basic biology, ecology and botany, conservation, statistics, GIS, remote sensing (critical for landscape scale), writing (you could be writing grants as often as once a month and will need to write up your results). It is important to be able to communicate both on paper and in person. There is a great deal of outreach so comfort talking to people and a friendly personality is necessary.

FL: Studies should include biology, botany and natural resource management. For seasonal employment, good grades, consistency and persistence are important. You will need critical writing skills and be able to communicate effectively to write field reports and notes.

Are there any tricks to the application process? (i.e. buzz words, CV vs. resume, etc.). What can you expect to negotiate for when interviewing/negotiating a contract?

DG: "Strategic Plan" know this statement for non-profit jobs and use it on your resume. We receive tons of resumes so you need to make yours stand out. Format the resume with experience at the top and education at the bottom and only include skills and training that pertain to the job you are applying for. Two good books to read are *Applying for Forces for Good*, and *Whole Communities*. Both will give you good key words to use in your resume. Definitely get outreach experience and practice presenting/writing at a fourth grade level so you can effectively communicate with a wide range of education levels.

JH: To get a state job, you have to get on the state lists. To do this, go to the state personnel board at spb.ca.gov and apply for an exam. Exams may come up once every two years or more frequently. To apply for an exam, get the bulletin and use action phases from the bulletin and feel free to define them broadly. For example, if the bulletin says monitoring experience and you have experience collecting data, don't put collecting data, put monitoring experience. If the bulletin says public speaking, you could say that you had public speaking experience while lecturing to an introductory biology class. The first people reading your exam will not know that these skills are very similar and transferable; they are just looking for the terms that are used in the exam bulletin. The applications can be saved on-line and tweaked for other exams. There is no resume in this process only the exam application. When preparing for the exam, use the required areas of knowledge and skills listed in the exam bulletin as a study guide. You will only get an interview if your score places you in the top three ranks. However, as people in the top three ranks become unavailable, the lower ranks move up. So while you may be in the sixth rank initially, within a year you may be in the third rank and receiving invitations to interview for specific jobs.

When you interview, use the Internet to learn about the department and program that you are interviewing for. Be prepared for the universal question: "How has your education and experience prepared you for this job." Interview questions often include hypothetical scenarios to see how you might approach and solve a problem or accomplish a project. Good things to keep in mind when starting out to tackle a project: What are your goals and objectives? What are the opportunities and constraints (staff, money, equipment, scheduling)? Who should you communicate with about your project (sharing information, gaining necessary approvals, safety, avoid duplication of effort, coordinating use of equipment or staff time – many reasons to think this through). The interviewer will appreciate that you consider these issues.

If you have a requirement that is an absolute dealbreaker (e.g., "I cannot possibly accept this job if I cannot telecommute three days per week") then let the supervisor know up front, before scheduling an interview. If there is no flexibility on either side of that issue, it's best not to waste time on an interview. If it's not a dealbreaker, but a preference (e.g. some telecommute days, or office hours that are outside the norm) avoid discussing your preferences until you are actually offered a job. Frankly, if you value making a very good initial impression on the job and can wait to institute the preferences, minimize special requests until after six months or a year of being a reliable employee. A supervisor may be more willing to accommodate a preference after they have learned through experience that you are dependable and that no one will need to do extra work as a result of the accommodation.

HG: You will need to submit a resume and it should be professional i.e. proofread it. Grammar errors are a bad sign. Show that you are willing to be flexible and leave no blanks on applications empty. Empty blanks tell us nothing and leave us guessing as to why you did not fill it in. If you have nothing to put in a blank, write N/A or unknown. If you do not have experience in a specific area, share an experience that demonstrates the quality we are asking about, like leadership or enforcement of rules. Before the interview, do research on the county you are applying to and their crops and current issues. Such info can be found on the CDFA Web site. This shows you have interest and initiative. Remember that the bureaucracy is slow moving so the process can be long.

EA: Combinations of outreach and research experience are needed. Your graduate research fulfills the research aspect, but outreach is often lacking in many applicants. For outreach, work with Cal-IPC, give talks, attend local, state and national meetings. If your resume matches the job, you have a shot. Also, have a job talk prepared. All university extension positions require a one hour presentation on which you are judged for the position.

FL: We use resumes and applications. It is best to talk with people you want to work for so that your resume stands out. It is better to have a face to the name, but even phone calls make a difference. Get experience in professional research and volunteer. Be consistent and persistent. Get to know someone in the federal government. You can do this by volunteering for them and working seasonally to get your foot in the door.

Open Questions

If I turn down multiple offers for a job, will I be removed from the state lists?

JH: After three rejections, they may classify you as inactive on the list. When you get on the list and say you are open to all regions, be sure to call and narrow the range if you are not actually going to take a job in a certain region. You can also go voluntarily inactive if you are temporarily unable to move for a job. This allows you to reactivate at any time as long as the list is still active by writing a letter to the administrator in charge.

Do you always need a resume or is a CV better and how long should it be?

DG: We want a resume, not a CV, and length doesn't matter.

How often are the SCAT positions available?

FL: Openings depend on the park and when they need people. Sometimes they will need people to fill in where they have been unable to find a permanent employee, i.e., hydrology. To get a leg up, do field work while you are in school and get to know someone in the program you want to work for, any position with the federal government. This may require you to move and live in rural areas. There are many applicants for this program so don't wait for a job announcement to come up. Get in there and get to know the people you would work for so they think of you when a job does come up. When I applied for my job, I looked at the list of biologists currently working for the agency and sent them my resume. I followed up with phone calls and volunteered. This networking allows you to get your foot in the door. You need to have to have all the skills plus something to stand out. Volunteering is also a good way to see what someone in the position you are interested in does and whether this is a good match for you

What is the master's job market versus the PhD? Are we at risk of being over qualified as a PhD?

The stereotype of a PhD being overly analytical is the issue here. If you are not this stereotype, you will be fine. It is more important to be sure that you have made you practical skills clear on your resume. The state and feds hire PhDs if they fit the job and often there are research positions that require a PhD. That being said, also be aware that there is educational jealousy out there.

Additional Advice

Shane Barrows (Catalina Island): Be able to answer the question "What do you want to do?" Of course none of us know exactly what we want to do, but have an answer for what you currently want to do. Not having an answer is a bad sign and having an answer gives the interviewer something to work with. You never know, you might get what you want if you ask for it.

HG: Be able to answer the question "Why should we hire you?" Not having an answer to this is not in your favor. Have questions for the interviewer at the end of the interview.

Thanks to all our great panelists and participants!

Preventing Introduction and Spread of Invasive Weeds via Construction Equipment and Supply Materials

Leader: Wendy West, UC Cooperative Extension, El Dorado County

Notetaker: Athena Demetry, Sequoia/Kings Canyon National Parks

The group first did a round of introductions and stated their particular concerns and interests. Some issues arising from these introductions included:

- How clean is clean (after equipment is cleaned)? Is there any science? (Yosemite NP)
- For contracts that say "weed-free materials," need to ID vendors for that. Are the vendors certified? (PG&E)
- Best Management Practices are often incorporated into contracts but harder to incorporate into an organization's internal operations (e.g. park equipment is not cleaned when moving between sites). (NPS: Sequoia/Yosemite)
- Yosemite started equipment-cleaning on a project basis and it is now institutionalized. They have someone that does equipment inspections for contractors. At what point do you turn them around? How do you know what to do? In an informal nursery experiment of dirt collected at an equipment-cleaning, there was 90% germination. Need science.
- In El Dorado Irrigation District, there is an annual training of multiple inspectors by the county. So they now have "certified inspectors."
- For stinkweed movement in the Bay area, what is a reasonable and practical precaution to take for routine work? Haven't come up with anything (Point Reyes).
- In Hawaii for *Miconia*, they have really strong prevention measures. They divide equipment up into Miconia or No Miconia. One person is assigned to wash clothes and look for seeds after control work. This training has expanded outside of NPS, and there is high awareness now.
- PG&E is considering purchasing a portable washing station (chlorinated) for about $30,000. Some Cal-Fire washing stations cost up to $100,000.
- Is this issue something the Invasive Species Council could take on?

Further discussion on sand and gravel pit inspection/certification:

- Mendocino County is starting a sand and gravel pit certification program. Some pits are managed for no vegetation at all (low-hanging fruit in terms of certification). Others are more difficult to rate. Using the Yellowstone model; forms are available at the Center for Invasive Plant Management and also using their survey protocol and rating key. Doing it as a voluntary certification program. If a pit doesn't come up to standards, they give input back on how to improve. The methods are out there—don't need to reinvent. This program has been adapted by NAWMA and by a majority of states.
- Who does the inspections? Yellowstone: counties do the inspections. Glacier National Park: park staff does the inspections.
- Challenges with the Mendocino program: Federal agencies are the best for requiring weed-free materials and are a good customer. If your area has a lot of federal agency demand for materials, you might have more success because you can get a critical mass of demand. With a lot of smaller, non-federal agencies in a county, it's more difficult to get that critical mass and to get buy-in. Cal Trans said that it's "a lot of trouble."
- In Mendocino, they inspect twice a year for growing plants. What about a seed bank? If there is a history of not seeing plants, then that's evidence that there's not a seed bank. For a known weed infestation, you could still scrape the topsoil, treat and use the material underneath.
- How is the Yellowstone program doing? Answer: 20% of the quarries passed right away. The rest had more work to do to come up to cleanliness, but not a big deal.
- It takes four full days to do an entire inspection of a pit (Truckee – Teichert).
- The state is a long way from quarry cleanliness being made mandatory.

Prevention for mulch materials:

- Are there safe mulching materials? NPS just had a post-fire mulching with "CA certified weed-free hay" and several weeds came from that hay.
- Wendy West pointed out the weaknesses in the inspection process for CA certified weed free hay. Counties have the choice of doing bale inspections (1 bale per 100 bales sampled) or pre-harvest field inspections. Bale inspections are very weak, but faster so often chosen. It's not a science-based process and is dysfunctional.
- Suggestions: Use rice straw (grown in an aquatic environment so there's as assumption that any weeds in there won't grow in dry sites). But others have seen some yellow star thistle coming in with rice straw (just a few plants), so it's not perfect.
- Suggestion: Check with International Association of Arboriculture or Utility Arborist Association

Prevention during fires:

- Resource Advisor (READ) for weeds is critical. Just showing up and being an advocate accomplishes a lot. If you don't show up, they're not likely to follow any written BMPs. Having READs on firelines and on the ground is critical.
- LA Water & Power provided an interesting case study of perennial pepperweed moved by equipment to eight other sites and how he educated the operator to care.
- Post-fire surveys are important. Inspect dozer lines.
- For the Angora Fire, the USFS had prevention protocols and thought they were ready, but found that it's very hard to implement during a fire. Others seconded this.
- Have training for everyone on staff, not just specialists, so that they have a basic understanding of weed issues in advance.
- NPS holds READ training every year or two and it's open to other agencies.
- Have prepared signs for staying off weeds. Put a price tag on it?
- Need an insider's view of how a fire camp works so you know where in the fire camp process to intercept crews for cleaning their equipment or vehicles.
- Have equipment washing contracts set up in advance at local car washes.

Group agreed to work to get prevention measures, contract language, etc. posted to Cal-IPC website to share resources already developed