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"Invasive Plants and Ecological Change"

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"Invasive Plants and Ecological Change"

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California Invasive Plant Council

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On the cover: Examining native and invasive aquatic plants on the dock at Emerald Bay State Park. Photo by Elizabeth Brusati

On the title page: Lake Tahoe requires inspections at boat ramps to prevent the spread of aquatic invasive species. Photo by Elizabeth Brusati

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Searching for invasive plants in a meadow at Grover Hot Springs during the Prevention field trip. Photo by Bob Case

Foreword

This year Cal-IPC celebrated our 20th annual symposium in Tahoe City. Our theme "Invasive Plants and Ecological Change" refers to the many forces acting upon both native and invasive vegetation, including climate change. Our first session addressed this topic specifically but many other speakers touched on it as well. Carla D'Antonio of UC Santa Barbara reprised her role from the very first Symposium as our opening speaker. Presenters included longtime veterans as well as students giving their first papers. We look forward to twenty more years of sharing information on invasive plants!

2011 was the first Symposium to feature snow. Photo: Bob Case

Ecological Change

Nuance, Naysayers and Twenty Years of Studying Species Impacts

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Understanding the impacts of invasive non-native plant species is fundamental to the creation of lists such as Cal-IPC's Wildland Invaders list that in turn can help managers to prioritize species for control. In the twenty years since the formation of Cal-IPC (and EPPC) scientific research on the impacts of non-native species has skyrocketed. Yet there are surprisingly few studies documenting the many purported impacts of both Cal-IPC listed and, more importantly, the few that evaluate the context specific nature of impacts. In addition an overarching framework for understanding impacts is lacking and the value laden nature of why we care about species has contributed to controversies about whether non-native invaders are indeed "problematic". In this talk I will discuss a framework for assessing traits that give rise to different types of species impacts as well as stressing some of the nuances of impacts for some presumed high impact invaders. Attention to the context specific nature of impact as well as to the subtleties of how species change ecosystems can help us refine the prioritization and management process.

The Ghost of Invasions Past: The Soil Legacy of Invasive Plant Species

Katharine N. Suding, University of California at Berkeley, Department of Environmental Science, Policy and Management, Berkeley, CA suding@berkeley.edu

Aside from their obvious disrespect for fence lines, some problematic invasive plant species can continue to edge out native species even after they have been removed due to their effects on soils. Evidence is accumulating that some invasive species can shift microbial communities, nutrient cycling and other soil processes, that the shifts in ecosystem processes may be advantageous to the modifying species, and that these effects may persist beyond the life of the invader. Similar legacy effects may also occur "top-down" through animal communities, changing trophic – rather than soil – interactions. Legacy effects might contribute to cases where restoration gets "stuck" with limited native recovery or where it takes a trajectory that leads to unintended outcomes. In such cases, invasive species management may need to consider setting control abundance thresholds and including additional intervention measures to address legacy effects.

Smog is Fertilizer: Atmospheric Nitrogen Deposition Drives Weed Invasions and Biodiversity Loss

Stuart B. Weiss, Creekside Center for Earth Observation stu@creeksidescience.com

The global nitrogen cycle has been massively altered by human activities. Emissions of nitrogen oxides and ammonia from combustion, agriculture, and soils are transported and chemically transformed in the atmosphere and deposited onto land and water. This atmospheric nitrogen deposition effectively delivers high quality nitrogen fertilizer to ecosystems. In California, 20%

of the land surface receives greater than 5 kg-N ha^{-1} $year^{-1}$, with hotspots receiving greater than 50 kg-N ha^{-1} $year^{-1}$. This profound ecological change enhances growth of invasive weed, and threatens native biodiversity. Documented effects include increased growth of annual grass and other invasives in coastal sage scrub, serpentine grasslands, vernal pools and deserts, altered nutrient cycling and fuel accumulation of montane forests, enhanced fire cycles and nitrate leaching into surface and groundwater, and eutrophication of montane lake, such as Lake Tahoe. Weed management is central to mitigating the impacts. This talk will review the scope of the problem in California and suggest some policy avenues, including CEQA, critical loads, mitigation fees to support Weed Management Areas, ESA consultations, Habitat Conservation Plans and other possibilities.

Fire, Climate Change, and Opportunities For Invasion

Max A. Moritz, University of California at Berkeley Environmental Science, Policy, & Management Department, Berkeley, CA mmoritz@berkeley.edu

Fire is an important process in many California ecosystems and human activities have altered natural fire regimes in a variety of ways. Natural fire regimes have also been altered by the spread of non-native species of plants, especially in southern portions of the state (e.g., annual grasses in both desert and shrubland areas). Climate change is very likely to disrupt future fire patterns, but shifts can be difficult to predict. In some locations, future fire activity may be driven by altered temperatures, yet in others it may be due largely to precipitation timing and/or amount. Future human development and fragmentation of natural landscapes will also play a role in many locations. A goal of this talk is therefore to review the varying constraints on fire in different ecosystems of California and some of the modeling approaches we have developed for predicting future fire probability patterns. While future fire could conceivably facilitate desired range shifts in some plant and animal species, fire is often considered an agent of vegetation "type conversion" when it provides a window of opportunity for invasion and establishment of non-native species. Such a window is much more likely when certain fire-related thresholds are crossed, such as the interval between fires. We will therefore also examine where the greatest disruptions in future fire frequency are likely in California, to assess whether the locations in question lend themselves to this kind of vulnerability.

Membership Meeting

Sustainable Forests, Healthy Communities and Vibrant Rural Economies

Kim Carr, Sierra Nevada Conservancy, Auburn, CA kcarr@sierranevada.ca.gov

The Sierra Nevada mountain range is the home to almost half of California's plant species. As the cost to monitor and control the plants is increasing, the federal and state land management funds are declining. These conditions are causing land managers to become more creative in addressing the problem by building broader partnerships to design projects to address multiple objectives, including invasive plant removal.

The Sierra Nevada currently has an unprecedented collaboration of diverse stakeholders addressing ecological restoration. These collaboratives are planning restoration work at a larger scale and across public and private lands. Furthermore, the discussions are including the relationship between ecological restoration and the myriad of services that are protected by healthy watersheds such as habitat, biodiversity, water quality and carbon sequestration. There is greater focus on the need for investment in the land and the people to advance ecological restoration and create local jobs to support rural community vitality. These new approaches help expand the traditional framework that has been used to address more specific challenges, such as invasive plants. This framework will be described by way of details of the Sierra Nevada Forest and Community Initiative and by providing specific examples of on-the-ground work.

Student Paper Contest

Germination and Growth Traits of *Dittrichia graveolens* – A Foundation for Developing Management Strategies

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Abstract

Dittrichia graveolens (L.) Greuter (stinkwort; Asteraceae) is a rapidly expanding and poorly studied annual invasive plant that is becoming a focus of resource managers in California. Currently, *D. graveolens* primarily infests roadsides, detention basins and mining facilities and requires additional management due to its asynchronous life cycle (late summer growth followed by flowering and fruiting in the fall). Potential for *D. graveolens* invasion in natural ecosystems is not well understood at present; better characterization of plant biology and life history traits is needed to assess this potential. Plants produce tens of thousands of small, pappus-bearing seeds that are easily dispersed by wind, vehicles and animals (including people). Based on its rapid expansion at a state level and effective seed dispersal at a local level, we focused our initial research on the germination and growth phases of the *D. graveolens* life cycle to better understand its capacity for establishment and persistence under a variety of environmental conditions. Preliminary results indicate that there is no innate seed dormancy and germination occurs with the first rainfalls of the season and throughout the winter and spring, as long as there is sufficient soil moisture. In addition, ger-

mination occurs at a wide range of temperatures (5°-35°C) and does not require light. Subsequent growth studies show that plants are dramatically suppressed by shade and that total annual growth is independent of germination date. Phenology of flowering is likely induced by photoperiod, with natural flowering beginning in mid-September. These germination and growth studies contribute to a larger research program that will describe the biology and life history traits of *D. graveolens* with the goal of improving our ability to predict its range expansion and developing effective and well-timed management strategies.

Introduction

The earliest records of *Dittrichia graveolens* in California are from the south Bay Area in the mid 1980's (H.T. Harvey s.n., UC /JEPS). The initial mechanism and time of introduction of *D. graveolens* in California are not documented, although many of the earliest collections are from the south and east Bay Area (Preston 1997). Dittrichia graveolens has now spread to at least 30 of 58 counties in California. Based on date and location data from herbarium records and on the increased concern by resource managers across the state, the invasion is considered to be expanding rapidly. The native distribution of *D. graveolens* is the Mediterranean basin and east through Turkey, Afghanistan and Pakistan (Brullo and de Marco 2000, Qaiser and Abid 2005). Occupied habitats in both the native and introduced ranges include heavily grazed rangeland, alluvial floodplains and disturbed areas with a variety of soil types including mine sites with heavy metals (Higueras et al. 2003).

The challenge in managing *D. graveolens*, as with many other invasive plants, is in determining the appropriate methods and timing of application. In California *D. graveolens* plants do not begin rapid above-ground growth until mid-June when many roadside and grassland management activities have already been conducted to reduce weeds and fuel loads. Managing *D. graveolens*, therefore, requires managers to carry out additional control activities thath can be costly and challenging to coordinate.

The goal of the *D. graveolens* research program is to build our understanding of plant biology and life history characteristics that can provide a foundation for the development of successful management tools. These experiments are designed to identify the environmental conditions that facilitate or limit establishment and growth. The program as a whole is in its initial stage and includes many studies of biology, life history and control techniques. Results from the first year of studies on germination and growth are presented here.

Methods

A series of experiments were carried out to investigate specific aspects of *D. graveolens* biology and life history. All experiments were conducted between October 2010 and October 2011 on the University of California – Davis campus.

Seed germination and temperature: A temperature table was used to germinate mature, filled seeds at the following constant temperatures: 5, 12, 16, 22, 27, 34, 44°C. Photoperiod was 12 hours light and 12 hours dark. For all germination experiments, seeds were considered germinated when both radicle and cotyledons were fully emerged from the seed coat.

Seed germination and shade: Germination under four shade conditions was assessed in a greenhouse experiment. Treatments of 50% light (Shade 1), 27% light (Shade 2), and 9% light (Shade 3) were tested along with a control (100% light). Four replicate trays with 36 cells (subsamples) were used for each treatment.

Seed germination under natural, seasonal conditions: A Latin Square design was used in the field to assess germination under natural conditions and in relation to natural climate and precipitation in an agricultural field on the UC Davis campus. Seeds were planted monthly from November 2010 to May 2011 with 100 seeds in each 15 cm diameter PVC ring. Seeds were counted and removed weekly as they germinated.

Growth, phenology, biomass and shade: Growth and phenology under shade conditions were assessed in a greenhouse experiment. Treatments of

50% light (S1), 27% light (S2), and 9% light (S3) were tested along with a control (100% light). Growth was measured by number of leaves, height and canopy volume (data not shown). Total above and below ground biomass was dried and weighed. Flowering time was recorded as it occurred for each plant.

Growth, phenology, and seasonality

A Latin Square design was used in the field to assess growth and phenology under natural conditions and in relation to local climate and precipitation. Seeds were planted monthly from November 2010 to May 2011 in 15 cm PVC rings. Leaf number, time of bolting and flowering, canopy volume and total above ground biomass were measured.

Results and Discussion

Mature, filled seeds of *Dittrichia graveolens* germinated over a wide range of temperatures with maximum cumulative germination (92.6%) observed at 22° C. Over 50% germination was observed for the range 12°-34° C and minimal germination (16.7%) was observed at 5° C. Overall seed viability was high (95.8%), based on results from a tetrazolium analysis. Together these results indicate that *D. graveolens* is very unlikely to have innate seed dormancy and thus should have a relatively short seed life.

There were no significant differences in germination of seeds sown in light and shaded conditions in the greenhouse based on ANOVA analysis ($\alpha = 0.05$). Average cumulative germination was between 50 and 75% for all shade treatments and the control. Under natural conditions in the field germination is closely linked to periods of precipitation over a very long period from December to June. The highest germination was observed between late February and mid-March. A small number of seeds germinated following rain in early June but did not survive past the cotyledon stage. Based on the combined results of the three germination experiments we conclude that germination is limited by soil moisture rather than temperature or light.

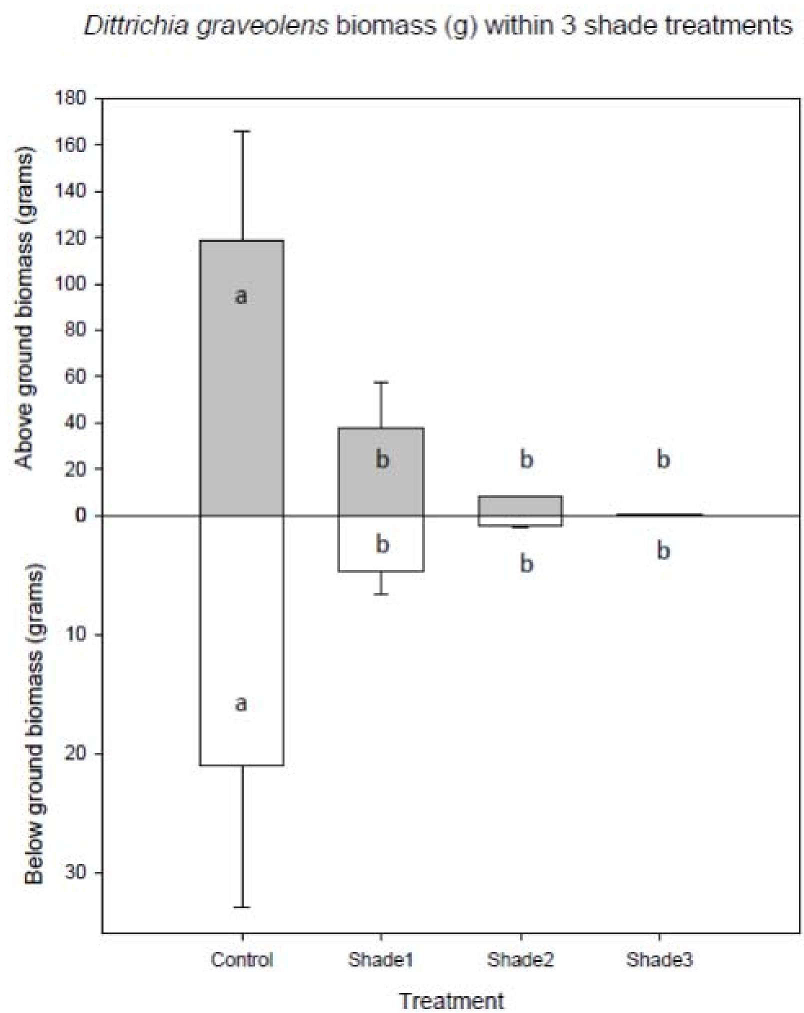

Figure 1:

Total above and below ground biomass of *D. graveolens* grown in three shade treatments in the greenhouse. Values are means ±1 SD

Total plant biomass was significantly reduced by shade (Figure 1) based on ANOVA analysis ($\alpha = 0.05$). However, shade did not inhibit flowering; all plants in the greenhouse shade treatments and control, along with plants in the field, initiated flowering within a two week period (September 1-15). The logical explanation is a photoperiod response, although we have not tested this directly. Above-ground growth of plants in the field was not significantly different between planting dates (November - May) at any point during the growing season. Plants began bolting during the second week of May and all plants had bolted by late May. The phase of rapid above-ground growth began in early June and did not slow down or level off by the time plants started flowering in early September, indicating that growth

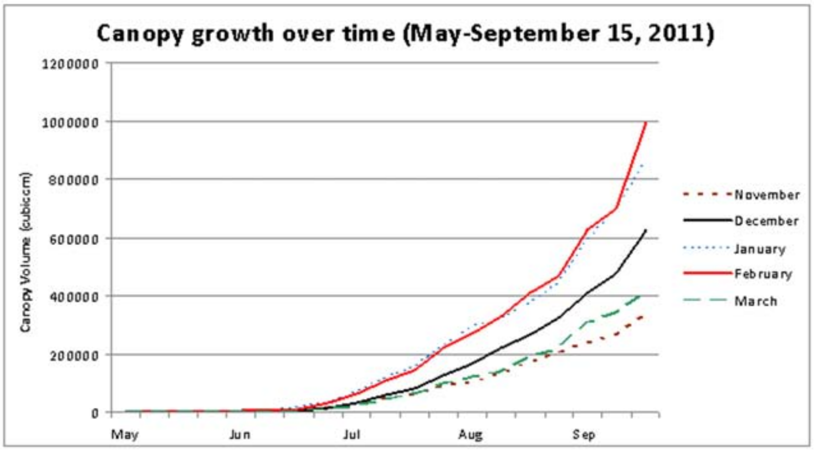

Figure 2

Dittrichia graveolens canopy growth of plants seeded monthly from November to March in field research plots arranged in a Latin Square.

is continuous over the growing season from June to September (Figure 2). The lack of significant differences in total growth between plants germinating early in the season (December) and those germinating later (April) indicates that there may be a particular relationship between degree days and growth.

Together, the data from the first year of research on the biology of *D. graveolens* establishes a baseline of understanding upon which we can begin to develop and test management alternatives. Additional studies will also be conducted to determine the potential susceptibility of rangelands and riparian habitats to invasion by *Dittrichia graveolens*. More information in the coming years will allow us to make recommendations with the goal of providing managers with tools to effectively manage this species.

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Alteration of Nitrogen Cycling Processes by Exotic Annuals in a California Grassland

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Abstract

California has a heterogeneous landscape with many diverse microclimates that house more than 1,000 exotic plant species. It has long been established that invasive exotic plants have the ability to impact aboveground biodiversity, but the effects of invasive plants on soil microbial communities and ecosystem nutrient cycling are much less understood. Soil microorganisms are potentially important mediators of invasion success in part because of microbial regulation of plant-available nitrogen (N) in soils; changes in N availability due to alteration of soil microbial communities during invasion may lead to competitive exclusion of native plants by invasive plants. The objective of our study was to assess how communities of invasive weeds (*Aegilops triuncialis* and *Taeniatherum caput-medusae*) and exotic forage annuals (*Avena fatua, Bromus hordeaceus, Lolium multiflorum* and *Trifolium subterranean*) affect total bacteria, fungi and soil N cycling in an experimental California grassland. Our results indicate that soils associated with invasive weeds had significantly higher soil carbon to nitrogen (C:N) ratios in the top 15 cm of mineral soil, lower total N and lower nitrification potential rates than native soils. Soil C:N ratios and total N values for soils associated with exotic forage annuals were not statistically different from those of invasive weeds. Additionally, total bacteria and fungi did not differ by treatment. Overall, our results indicate that soil N dynamics were impacted by the presence of invasive weeds.

Introduction

Biological invasions constitute a significant part of global environmental change, often resulting in alterations to critical ecosystem services. An understanding of how invasive plants affect soil nutrient dynamics and utilizing this knowledge during control and restoration efforts, may aid in the stable maintenance or reestablishment of desirable species (Heneghan et al. 2008). Of particular interest is soil N cycling, because N is often the limiting nutrient for plant growth and thus acts as a regulator for competition among native and invasive plants. As such, it is important to understand if and how invasive species affect N cycling so that land managers can implement soil amendments to help increase the successful reestablishment of desirable plant communities. Investigating associated changes in the soil microbial community may also be of benefit for two reasons: the microbial community may be an indicator of the trajectory of a restoration project and direct manipulations of particular microorganisms may aid smaller, targeted restoration projects.

The purpose of this study was to investigate how N dynamics shift in response to invasion events. Two different invasion scenarios were created: one scenario consisted of invasive plants that were introduced to California in the late 1800s and are considered "old" invasives; the other scenario consisted of invasive plants that have experienced a more recent spread throughout California and are thus considered "new" invasives (see methods). We hypothesized that N cycling associated with invaded communities would differ from native communities and that "old" invasives would have intermediate values between "new" invasive and native communities. We also hypothesized that shifts in microbial communities would accompany shifts in N cycling.

Methods

This study was part of a larger project initiated by Principle Investigator Valerie Eviner, Kevin Rice and Carolyn Malmstrom. Located near Davis, California, it was established in 2006 and the experimental design is a randomized complete block design with 1.5x1.5 m plots replicated factorially. On April 4, 2011, we sampled soil from three vegetative treatments: communities of invasive weeds (new "weeds:" *Aegilops triuncialis* and *Taeniatherum caput-medusae*), exotic forage annuals (old "annuals:" *Avena fatua, Bromus hordeaceus, Lolium multiflorum* and *Trifolium subterranean*), and native species ("natives:" *Bromus carinatus, Elymus glaucus, Leymus triticoides, Lotus purshianus, Lupinus bicolor, Nassella pulchra, Poa secunda* and *Vulpia microstachys*). Within each plot, we composited five randomly selected soil cores from the top 15 cm of mineral soil and placed them in a cooler (4° C) until processed in the laboratory at UC Merced. Soil characteristics that were measured included total C and N, nitrification potentials (Hart et al. 1994), pH and soil moisture (Robertson et al. 1999). Microbial measurements included total bacteria and fungi using direct counting (Ingham et al. 1991). Analysis of Variance (ANOVA) was performed in 'R' statistical package to determine treatment effects among the different variables.

Results and Discussion

Our results indicate that, after only five years following plant community establishment, soils associated with invasive weeds had significantly lower soil total N than native soils ($p < 0.05$), with exotic forage annuals having an intermediate value of total N (Figure 1). Total C did not differ

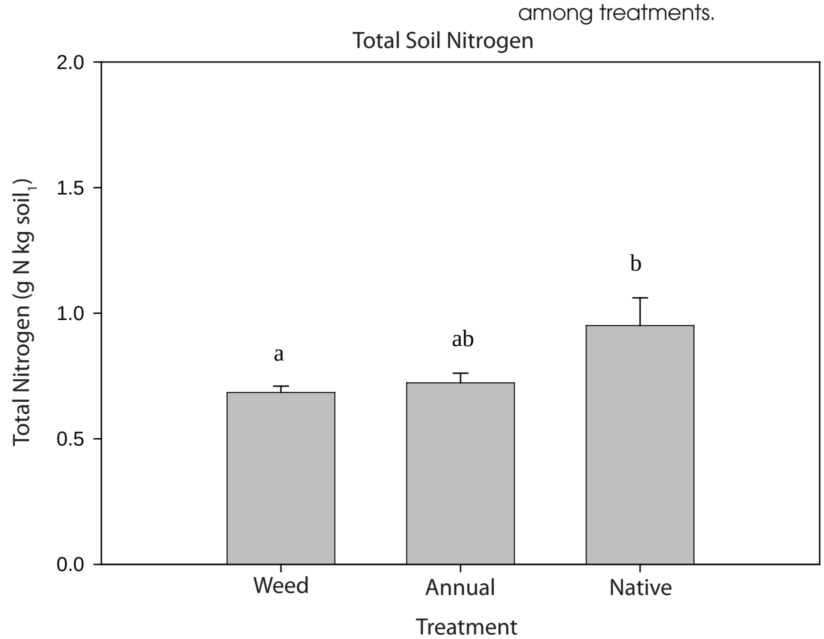

Figure 1

Total soil nitrogen by treatment. Error bars represent standard error of the mean. Different letters denote significant differences among treatments.

significantly among treatments (data not shown). The C:N ratio of the soil was not different between invasive weed and exotic forage annual treatments; however, the C:N ratio was significantly lower under native soils ($p < 0.05$). Nitrification potentials exhibited the same pattern as total N. Potentials were significantly lower in the invasive weed treatment compared to the native treatment ($p < 0.05$) and the exotic forage annual treatment had values that were intermediate between the invasive weed and native treatments (Figure 2), thus supporting our first hypothesis. Soil pH and moisture content were not affected by treatment. Our second hypothesis, that the soil microbial community would be affected by treatment, was not supported because total fungi and bacteria counts were similar among treatments.

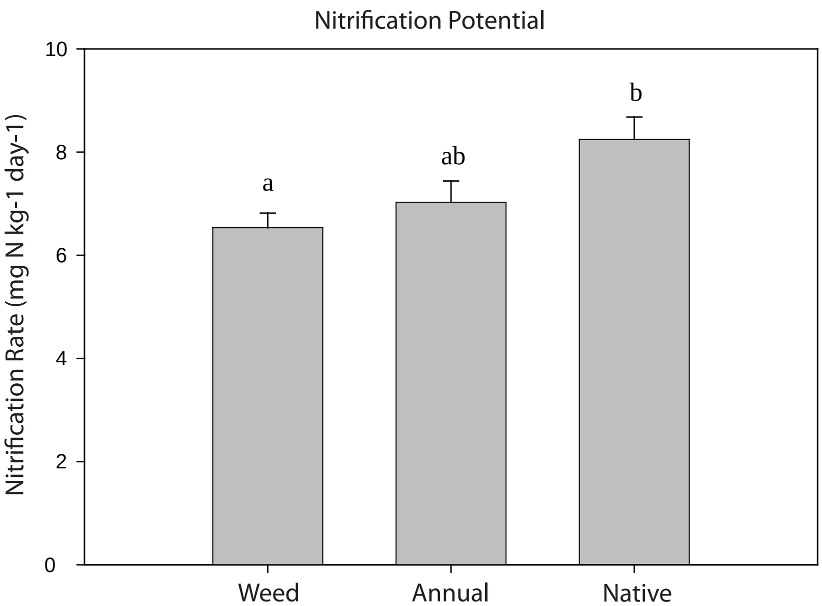

Figure 2

Nitrification potentials by treatment. Error bars represent standard error of the mean. Different letters denote significant differences among treatments.

The reduction in soil total N and potential rates of nitrification suggests an overall decline in the rate of N cycling in invaded compared to native soils. This conclusion is in agreement with results from Drenovsky and Batten (2007), which showed higher litter C:N and lignin:N ratios and thus slower aboveground decomposition rates of Barb goatgrass when compared to native plants. Moreover, Swenson et al. (1964) reported a high silica content in medusahead litter, a characteristic that might also slow nutrient cycling in soils. Soils under "old" invasive weeds showed values of total N and nitrification potentials that were intermediate between native soils and soils invaded by "new" invasive weeds.

Interestingly, total bacteria and fungi did not vary significantly by treatment. This is surprising because fungi are better able to degrade lower quality (higher C:N) litter than bacteria, thus a shift in litter from high quality (native plants) to lower quality (invasive plants), as suggested by the studies mentioned above, should induce a shift in the bacteria:fungi ratio. However, the shift in soil C:N ratio in our study was due to variations in N, not C, and this may explain why the total microbial biomass hasn't changed. Moreover, there may be compositional shifts in the microbial community that can only be seen at a finer scale.

This research suggests that *Aegilops triuncialis* and *Taeniatherum caput-medusae* can significantly alter N cycling dynamics from pre-invaded conditions. Because N is the primary limiting nutrient in many temperate ecosystems, it may be necessary for land managers to make N amendments to the soil that tip the competitive balance back in favor of native or naturalized species. For many invasion events, this would require reducing total soil N (Ehrenfeld 2003); however, for this scenario, it would require increasing the N pool through N additions. Additional feedback experiments need to be conducted in order to confirm whether a shift in N regulates invasive plant abundance in this situation. Our conclusions bring up an important point that many ecosystem-level effects of invasive plants are context dependent and, in order to appropriately manage an invasion event, one must first identify plant-soil interactions that may be mediating the response of the ecosystem to restoration efforts (Eviner and Hawkes 2008). By elucidating critical links between structure and function and contributing to scientifically-sound approaches to restoration, our research should prove useful to land managers.

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How Does Light Attenuation Affect Giant Reed (*Arundo Donax*) Establishment?

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Abstract

Giant reed (*Arundo donax* L.) is an invasive, asexually reproducing clonal grass brought to California for stream bank erosion control and now infests riparian habitats in much of the state. A greenhouse experiment was conducted to test how carbon starvation affected *A. donax* establishment, simulating light competition from cultural control. Shade structures were fabricated creating three shade treatments (100, 35, and 5% ambient light, r = 3) with destructive harvests at three and six months. Plants receiving 5% light displayed rapid stem elongation, had fewer leaves, and less total leaf area than in higher light treatments. Plants in the 100% and 35% light treatments looked robust and healthy with similar total leaf area and stem height, but had different RGR and R:S. There was a direct relationship between available light and resource allocation with plants grown in high light allocating more carbon to root mass and belowground storage, whereas shade grown plants allocated more to light-harvesting organs. Results indicate that carbon starvation alters *A. donax* resource allocation and only under deep shade are both above and belowground growth negatively affected, making these plants susceptible to herbivory and drought. Management utilizing restoration practices that maximize native shading potential, such as through species selection and planting density, could reduce *A. donax* success and provide long-term control when used as part of an Integrated Weed Management Program.

Introduction

By studying invasion mechanisms and creating control and restoration strategies based on ecological principles, invasive species management has been shown to be most effective (Radosevich et al. 2007). Giant reed (*Arundo donax L.*) is an invasive perennial, clonal grass, similar in appearance to bamboo that has been transported throughout the world for its many uses (Bell 1998). Reproduction is strictly vegetative in California and dispersal of stem fragments occurs during flood and anthropogenic disturbances (Else 1996, Bell 1998). Quinn (2006) defined *A. donax* as having a ruderal-competitive life history strategy that lends a competitive advantage over native riparian species after flood disturbance. During this period resources are plentiful and space is available for recruitment. Large, energy rich propagules enable rapid shoot growth, where elongation is maximized under light-limiting conditions (Else 1996). Once established this plant alters the riparian ecosystem, creating monotypic stands. The focus of my dissertation work is to determine how vulnerable *A. donax* is to carbon starvation and what factors play major roles in suppressing growth and minimizing reinfestation within management areas.

The ability to form a closed canopy has been described as a mechanism whereby riparian communities resist invasion (Galatowitsch and Richardson 2004). Riparian restoration typically includes planting locally collected branch cuttings of shrubs and trees that establish quickly, creating dense thickets of native canopy. Sandbar willow (*Salix exigua* Nutt.) and mulefat (*Baccharis salicifolia* (Ruiz & Pav.) Pers.) are native riparian shrubs that have been indicated as good competitors with *A. donax* (Coffman 2007).

My previous research found that in competition with *B. salicifolia* in a simulated restoration planting *A. donax* growth was significantly decreased and negatively correlated with shrub planting density and leaf area index (Palenscar unpublished data). To compare the effects of shading alone a shade experiment was conducted to test how carbon starvation affected plant growth and carbon allocation. It was hypothesized that carbon starvation would cause a reallocation of resources maximizing aboveground growth with limited growth occurring once stored carbon reserves were consumed, increasing with the percentage of light restriction.

Methods

Research was conducted in a glasshouse at the University of California, Riverside on the center three-wire mesh-topped tables. Center tables were chosen to minimize morning and evening structural shading. Shading treatments consisted of shade structures (1 m^3) constructed with ½ inch polyvinyl chloride (PVC) pipe supporting neutral density shade cloth, creating three treatments (100% (control), 35% and 5% ambient light) and three randomized blocks, blocked with the solar angle. Ambient light intensity was verified per structure with a LiCor photosensor (LI-190 Quantum Sensor) prior to planting. The lowest light intensity treatment (5%) was chosen since it is similar to the ambient light environment beneath a restored mulefat canopy (Palenscar unpublished data).

A. donax rhizome fragments were harvested from a local source (February 12, 2010) and held at 4° C until planting (February 16, 2010). Rhizome fragments were trimmed to a standard size (30 +/-5 g) with one obvious bud and planted (300 total) into steam-sterilized four-inch pots with UC Mix #2 and riparian soil inoculate (10 g/pot). To control for plant age only the middle cohort (defined by emergence date) of 117 plants were used for the experiment. Plants were then repotted to one-gallon steam-sterilized pots (Feb. 25, 2010) and randomized with thirteen per treatment structure. Pots were watered daily for one minute and fertilized (one tablespoon/plant) every three months with Osmocote (14-14-14, granular slow-release).

Photosensors (Hamamatsu gallium arsenide photodiode – G1115) were calibrated against one factory calibrated LiCor PAR photosensor on Mar 13, 2010. Sensors were then placed on 24-inch risers and leveled within each shade structure. Transmitted light and air temperature were measured continuously on a datalogger (CR23X Micrologger). Two destructive harvests were made at three (May 18, 2009) and six months (August 17, 2009) after plant emergence. Plant organs were divided into leaves, stems (aboveground and rhizomes separately) and roots and dried at 69° C for three weeks in a large drying oven. Biomass was assessed for relative growth rate (RGR) and resource allocation per treatment. Leaf area was measured on a leaf area meter (LI-3000) and light curves were created using a portable photosynthesis meter (CIRAS-1) at 0, 20, 90, 180, 480, 970, and 1500 μmol $m^{-2}s^{-1}$. Statistical comparisons were made using Statistix (version 9).

Results and Discussion

The relationship between plant growth and light intensity was logarithmic between treatments

(August harvest, $r^2 = 0.93$). Root to shoot ratios displayed proportionally more allocation to roots than to aboveground organs, increasing with light availability for both harvests. With age all plants significantly increased carbon allocation to shoot mass with the 5% treatment experiencing the least change. RGR decreased with plant age for the 35% and control treatments but significantly increased for the 5%. Absolute net growth was proportional to available light for the 5% treatment, with plants attaining 6% (16.5 g) net biomass relative to control plants (268.7 g), whereas the 35% treatment attained 58% (156.5 g) relative to the control. When comparing relative proportions of above versus belowground net biomass, the 5% treatment allocated twice as much carbon (1.22) and the 35% treatment 27% more (0.74) than the control treatment (0.58). This allocation to aboveground growth was observed in the first harvest where shaded plants invested in fewer, larger leaves, longer internodes and taller stems. Total leaf area was not significantly different between the 35% treatment and the control for either harvest, but became significantly different for the 5% treatment after the second harvest.

Analysis of light curves indicated that both the 5% and 35% treatments displayed photosynthetic acclimation at low light (hv = 40 μmol $m^{-2}s^{-1}$) and decreased rates of dark respiration when compared to the control. Only the 5% treatment had positive rates of photosynthesis at this low light intensity, which was the average light intensity from 10am to 2pm in the 5% treatment structures during the growing period. This photosynthetic acclimation of the 5% treatment allowed *A. donax* to persist and grow even under extreme light-limiting conditions.

Results indicate that carbon starvation alters *A. donax* resource allocation to aboveground plant organs, leaving these plants susceptible to herbivory and soil drying. Under dense shading (5% treatment) these plants are especially vulnerable to even moderate perturbations. Selection of drought tolerant riparian shrubs, like mulefat, may provide cultural control through resource competition. Management utilizing restoration practices that maximize native shading potential, such as through species selection and planting density, could reduce *A. donax* success and provide long-term control when used as part of an Integrated Weed Management Program.

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The Importance of Landscape Context in Invasive Plant Patterns Within Conservation Linkages

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Abstract

Conservation linkages, such as highway undercrossings, hedgerows and riparian corridors, are widely promoted to combat the negative effects of fragmentation. An often-discussed though understudied concern is that linkages will also aid invasive plant movement. Edge habitat has often been linked to invasion and because of their relatively long and linear shape, conservation linkages could

promote plant invasion. This consequence may largely depend on a linkage's landscape context, such as the nature of the surrounding matrix (the land surrounding linkage). As part of a broad study to address the potential problem of linkages encouraging invasive plants, I collected data from nine large-scale conservation linkages in San Diego and Riverside Counties. Surveys confirm that plant invasion often has a spatially explicit structure with linkage interiors being more invaded than their edges. Preliminary results show that matrix land cover type is a significant factor in the presence of certain species along linkage edges. In addition, these matrix-dependent edge patterns can vary between invasive species based upon their different dispersal syndromes (wind vs. animal vs. bird). Therefore what constitutes a landscape for a wind-dispersed invasive species is not the same as that of an animal-dispersed invasive species or a bird-dispersed species. Few if any studies have examined this landscape ecology concept in a comparative, large-scale manner. Conclusions from this research will help land-managers/owners prioritize invasive plant management within their linkages and will advance our conceptual understanding of invasive plant patterns and connectivity at the landscape level.

Introduction

Connecting the natural landscape is an intuitive idea that has garnered support from all types of conservationists (Beier and Noss 1998, Anderson and Jenkins 2006). Conservation linkages (also known as corridors), strips of land meant to connect habitat patch A with habitat patch B, constitute the most popular type of connective feature. While linkages are meant to enhance native plant and animal movement in our increasingly fragmented natural world (Beier and Noss 1998, Anderson and Jenkins 2006), many have also postulated that those same linkages may also help unwanted species (e.g., invasive plants) and processes (e.g., spread of disease) (Beier and Noss 1998, With 2004). Although these potential downsides to conservation linkages often have been mentioned, they have rarely been examined (for two exceptions, see Damschen et al. 2006 and Deckers et al. 2008). Our research on plant invasion in conservation linkages addresses this missing piece of the connectivity puzzle, impacting both basic and applied ecological knowledge.

The effects of conservation linkages on invasive plant patterns are likely driven by 1) high edge:area ratios in linkages and 2) the role of the matrix. First, because of their inherent shape (relatively long, linear, and narrow), linkages have a greater edge:area ratio than the habitat patches they are meant to connect. This increases the possibility that invasive plants, often associated with edge habitats, will both invade along the linkage and also move through the linkage into the connected habitat patches (Deckers et al. 2008). Second, invasive plants turn another aspect of connectivity on its head: the role of the matrix. For native species, conservationists are concerned with how focal species can bypass or move through the matrix. For invasives, however, the source patches may often be the matrix itself (Rodewald 2003). The concern then becomes how different types of matrices differentially affect patterns of invasion from the matrix into the linkage. This adds a critical landscape variable to consider when assessing how linkages affect invasive plant connectivity.

To start to address this pressing conservation issue, I used large-scale landscape linkages in Southern California. Specifically, I sought to answer:

1) Do invasive plant patterns change with distance from edge? (Spatially-explicit)
2) How do different types of matrices impact those patterns? (Landscape context)
3) Are those patterns driven by the species' dispersal modes? (Species ecology)

Methods

I collected data from nine linkages dominated by chaparral and coastal sage scrub in San Diego and Riverside Counties. These are linkages outlined in 1) the Western Riverside County Multiple Species Habitat Conservation Plan and 2) the San Diego Multiple Species Conservation Program. I chose 45 focal invasive species or species groups (e.g., *Erodium* spp.) based on importance to local land managers and/or if they were rated moder-

Figure 1

A) A suburban housing development with minimal open, green space (poor "animal dispersal" matrix). B) A wildlands matrix with no obvious movement impediment (good "animal dispersal" matrix).

ate to high priority by Cal-IPC. To choose data collection sites, I differentiated between matrices based on predicted ease of plant dispersers (wind, animal and bird). For example, a densely packed suburban housing development would classify as a poor "animal dispersal" matrix since there is little open, green space for animals to move between the matrix and linkage, whereas a wildlands matrix would be a good "animal dispersal" type since there is little obvious obstruction to animal movement across that matrix-linkage boundary.

At each site, I collected data on focal species presence and percent aerial cover within the linkage. I ran two line transects along the edge (100m) and from the edge toward the interior of the linkage (200m) to survey focal species presence. Along the edge transect, I set up three block (6m x 6m) sampling sites to collect cover data and four additional cover blocks along the edge-interior transect.

Results and Discussion

Preliminary results show that there is indeed a spatially explicit pattern of invasion for my focal species overall ($p < 0.0001$), but the direction of that trend varies. There are mixed distance effects within the grass guild ($p = 0.03$) as some species (e.g., *Vulpia* spp) decrease in cover away from the linkage edge, while others (e.g., *Avena* spp) actually increase in cover. Forb cover generally decreases from the edge toward the interior ($p < 0.0001$).

General land cover matrix type is a significant factor in the presence of *Avena* spp. ($p = 0.04$,

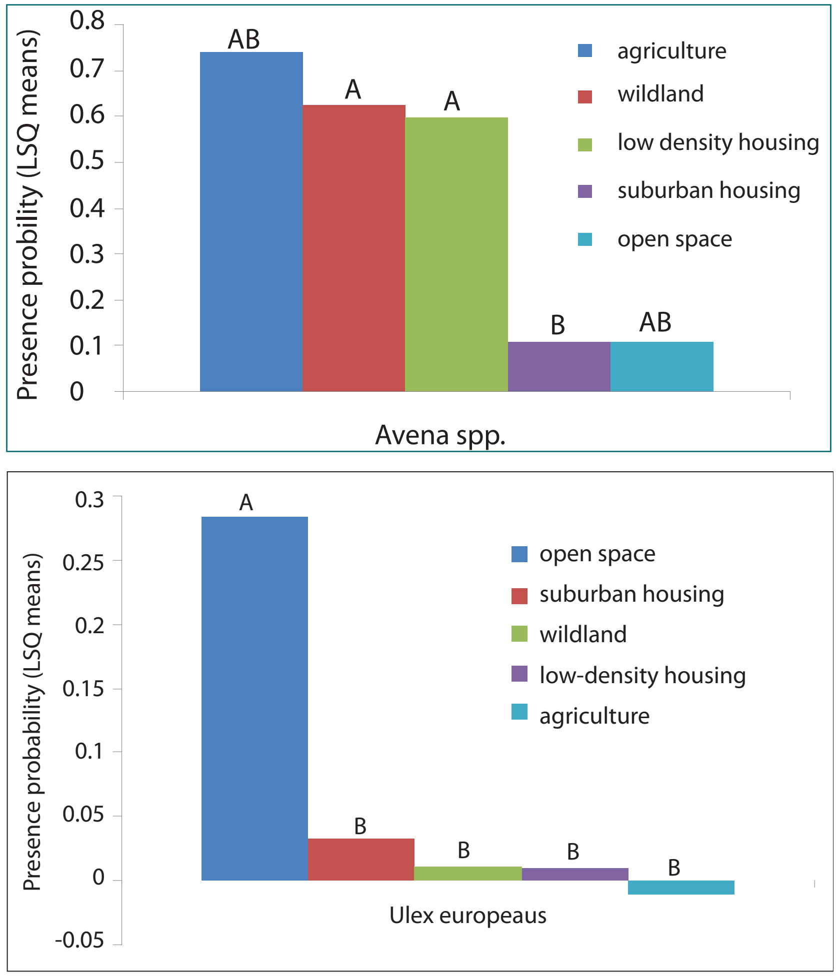

Figure 2

A. *Avena* spp. has the highest probability of occurring within a linkage at a site adjacent to wildland, low density housing, or agricultural matrices. B. *Ulex europeaus* has the highest probability of occurrence at a site adjacent to open space matrices. (The letters denote statistically significant groups based on the Tukey test.)

ANOVA) and *Ulex europeaus* ($p < 0.0001$) along edges (Figure 2). The way in which land cover affects the presence of these species differs (see Figure 2). From the edge into the interior, land cover matrix also is a significant factor for the presence and cover for *Avena* spp. ($p = 0.02$, ANOVA), Erodium spp. ($p = 0.03$), and *Ulex europeaus* ($p = 0.04$). As for dispersal matrix types, preliminary analysis shows that total invasive forb cover is significantly higher for matrices that were a priori designated as "poor" wind dispersal matrices and also for "poor" animal dispersal matrices.

With just this preliminary analysis, I can start to see that there is a difference between edge and interior within conservation linkages with respect to invasive plants and that the type of matrix may have an impact on what invasive species are present and at what abundance in a given area. The latter idea supports the idea that there are different "landscapes" for different invasive species and/or groups. This has direct relevance to linkage planning and management. For example, if wind-dispersed invasive plant species are more prevalent in a linkage when adjacent to suburban housing development, land managers may alter their prevention or control techniques to reflect that (as opposed to actions for animal- or bird-dispersed species). While my current results are suggestive, they are not conclusive, but after incorporation of historical land management data and further detailed analysis, I will have a much richer story and take-home message to provide for all stakeholders (landowners, managers, researchers, etc.). My final results will enable land managers in Southern California and, ideally elsewhere, to prioritize invasive plant management in a spatially-explicit, landscape context-dependent manner within their linkage. I hope to help provide one more crucial layer onto holistic conservation linkage management.

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Prevention

Working with Aggregate Producers and Suppliers

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Abstract

Invasive weeds are a major problem in California and the Sierra Nevada Mountain region, negatively impacting water quality, forest productivity, recreational opportunities and wildlife habitat. New weeds continue to move into the region and are establishing in native plant and forest communities once considered resilient as climate change and nitrogen deposition create more opportunities for invasive plants. The numbers of vectors for invasive plants also increase with an increasingly mobile populace. Contaminated aggregate (sand and/or gravel) used in road construction and maintenance is a primary vector for invasive plant spread. Contaminated gravel can spread invasive plants along hundreds of new, freshly disturbed sites. Thus, working with quarry operators to treat invasive plants at the source represents a cost-effective alternative to massive roadside infestations and subsequent treatment. This presentation will highlight current efforts to: identify and promote programs that support the production, availability and use of weed-free aggregate; develop and disseminate educational materials to quarry operators to build awareness and understanding of the issue; develop, expand and support material invasive plant cleanliness verification programs. While ultimately this is a prevention program, this program also functions as an outreach service to quarries by providing botanical skills and access to resources necessary for effective weed control. Successful participation in this program by quarries provides a marketable certificate that can increase the value of a quarry's aggregate.

Introduction

Weed treatment is an expensive, yet obvious way to manage the degradation caused by invasive plants. Prevention is well-cited as the most cost-effective alternative, but the most appropriate strategy is not always apparent. Roadsides and developed areas harbor weeds because they are perennially disturbed and new weeds seeds are continuously introduced. The most significant introduction vector are road construction and maintenance activities; therefore they are the most cost-effective group to use best management practices to prevent dispersal and establishment of invasive plants. Gravel pits and quarries are perennially disturbed and therefore high quality habitat for many weeds. Weed seeds are moved or blown around the quarry and end up in recently mined material. The contaminated aggregate is then transported to a project site and distributed into another disturbed area. Early establishment of weeds creates an uphill battle for native plant establishment and restoration efforts. Therefore, working with quarry operators to treat contaminated quarries is the most obvious and cost-effective method to preventing weeds from establishing along roadsides and disturbed areas.

Case Studies and Inspection History

Contaminated gravel has been documented as a new infestation source by land managers across the United States, especially in national parks and forests. Examples include:

Staff at the Klamath National Forest discovered an infestation of dyer's woad (*Isatis tinctoria*) in 2006 in the Salmon River watershed along five miles of forest road leading to a trailhead, within one mile of the wilderness boundary. The resulting infestation has been treated manually but continues to spread, particularly after a fire in 2008 when it moved into the burn in two areas.

At Great Smoky Mountains National Park in Tennessee, park staff began suspecting gravel as a seed source about ten years ago after seeing white sweet clover growing out of stockpiled gravel. Then coltsfoot (*Tussilago farfara*) came up along a transmountain highway where small gravel and sand (chat) are used in winter. Coltsfoot was found nowhere else in the Park at that time. Then the same plant was found growing out of gravel on a recently graveled driveway; both were isolated infestations with no others anywhere nearby. Uninspected gravel quarries were linked as the vector source for the new infestations.

Over the years, a National Parks SWAT team had mapped all priority weed infestations in Golden Spike National Historic Site in Utah, but suddenly new infestations of dyer's woad (*Isatis tinctoria*) sprung up along miles a railroad grade. As it turned out, the park had brought in gravel from Brigham City to shore up the grade, and no source inspection had been conducted.

An area in Sublette County, Wyoming had black henbane (*Hyoscyamus niger*) in a gravel pit. Aggregate from the infested pit was then used on oil field roads. New henbane infestations were soon spreading along the roads.

The El Portal Road Reconstruction project outside Yosemite National Park followed immediately after a flood event in 1997. Emergency repairs of several miles of roadway required the import of fill dirt extending up to seventy five feet from the road edge. No source inspections were conducted and the following season, many new invasive plant infestations sprung up. Hundreds of thousands of dollars have been spent to clean up the worst of the problems, but many of the annual grasses, clover and vetch remain.

Gravel pit inspections have been instituted by a variety of agencies across the West in the past fifteen years, with inspections beginning in some areas of California as early as 2003. The Sublette County, Wyoming Department of Transportation required inspections of gravel pits in 1995. The North American Weed Management Association (NAWMA) developed inspections standards in 2007. The US Forest Service (USFS) Lake Tahoe Basin Management Unit has been inspecting gravel pits since 2003, annually providing each operator with a letter authorizing use, or denying use, of their products for Forest Service projects in the Tahoe Basin. Yosemite National Park also has an active inspection program, begun in 2009, for gravel products used within park boundaries.

Producer Incentives

An agreement between land management agencies and companies to purchase/supply weed-free aggregate creates a market driven solution to weed spread problems. A shared program between land managers and suppliers strengthens product visibility and demand, thereby indirectly boosting financial incentives for suppliers to participate. Many quarry managers are already concerned about both the quality of their product and their environmental impact. This program helps quarry managers address those concerns as weedy aggregate is both low quality and an environmental liability. Ultimately, gravel pit owners and managers also realize the cost saving in eradicating invasive weeds in the facilities when infestations are small and controllable. Cost savings can also be realized by managers implementing best management practices for cleaning equipment prior to returning to the facility to stop re-infestation.

Quarries have financial incentive to participate in an inspection program, but they may not have the financial resources or knowledge base to develop an effective weed abatement program. Therefore, the inspector serves dual roles as both inspector and educator. The success of this program hinges on the collaboration between inspectors and quarry managers to develop an integrated pest management program for each quarry. Inspectors work with quarry managers to develop weed identification skills and provide educational materials to guide managers to develop a successful program. Together they develop a plan that prioritizes weed treatment based on aggressiveness of each species, the appropriate tools and techniques and the appropriate timing of treatment. The Cal-IPC Web site will have a section tailored to quarry managers that provides guidance on the appropriate herbicide for each species, and specifics about tools and techniques.

Inspection Methods

With a regional inspection program, land managers would designate an inspector to certify aggregate pits for a buying consortium. Land managers reduce the costs associated with maintaining a weed-free aggregate program by sharing the inspector, the verification certificate and the small cost of a quarry gaining weed-free status i.e. treatment costs passed onto the consumer.

Inspectors and quarry managers locate and map infestations throughout the quarry. Additionally, they identify neighboring properties and areas where weed seed might be transported into the quarry. Once the weeds are identified and mapped, they develop an integrated pest management program. After a program has been implemented, inspectors inspect and rate the quarry in order to gain certification. The ratings are:

Full passing – All members of the consortium can purchase weed-free aggregate in good faith.

Conditional passing – Material taken from the quarry should be used with caution, as some material may not be weed-free. There is some risk in using this material.

Not passing – Member of the consortium will not purchase aggregate from these quarries.

The inspector helps quarry managers reevaluate and readjust the implementation of their weed management plan, if necessary, to work towards certification if the quarry receives a conditional or non-passing rating. Quarries are inspected periodically (annually or biannually) in response to changing weed populations to evaluate the efficacy of treatments and because different species are easier to identify according to the time of year. In the near future, the Cal-IPC website will have resources for land management groups looking to purchase weed-free aggregate.

Prevention Best Management Practices for Invasive Plant Managers

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Abstract

Throughout the community of land managers in California, several best management practices (BMPs) are used to reduce the introduction and spread of invasive plants. However, there is not a single set of BMPs used. To address this need, the California Invasive Plant Council developed a set of prevention best management practices (BMPs) for land managers. The goal of these BMPs is to prevent accidental introduction and spread of invasive plants by those managing invasive plants in California. This manual provides essential guidelines for integrating prevention BMPs into land management. The BMP manual is now available at www.cal-ipc.org.

While conducting restoration work, land managers often travel between worksites. Equipment, vehicles, animals, clothing, boots and mulching materials moved between sites can become vectors for the introduction and the spread of invasive plants. However, this can be prevented if standard prevention practices are followed. For example, equipment cleaning and use of weed-free materials. These prevention BMPs also aim to help land managers make efficient use of limited resources, as the least expensive and most effective way to manage highly invasive plant species is through prevention.

Background

In partnership with Cal-IPC, an amazing technical advisory team, made up of land management experts across the state, reviewed existing resources to develop this manual of key prevention measures for terrestrial invasive plants. This prevention BMP manual is a living document therefore we encourage feedback in order to make the manual and the checklists more useful on-the-ground.

How to Use This Manual

Land managers can use the material in the manual to conduct trainings for work crews, provide language for contractor specifications for work on their land and to develop educational materials for the public. Each BMP is appropriate for particular situations; managers can select those that are practical for their use. As land managers being aware of potential vectors for the spread of invasive plants is critical to meeting conservation goals.

Prevention practices are essential for limiting the introduction and spread of invasive plants. Working effectively and efficiently will better enable California's land management community to be successful in meeting long-term conservation challenges.

Download the BMP manual from www.cal-ipc.org.

Acknowledgements

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Challenges to Early Detection and Rapid Response – Spotted Knapweed Eradication: Building Successful Partnerships Between Local, Federal and Private Entities

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Spotted knapweed, an "A" rated pest by California Department of Food and Agriculture, was discovered in the "Cleveland Fire" area of the Sierra Nevada Mountains in El Dorado County. The Cleveland Fire burned 22,485 acres in 1992 after a small five-foot fire exploded in a matter of hours. Spotted knapweed was most likely brought in on equipment used during fire suppression, erosion control and timber salvage efforts. The site was initially found on private timber property, but soon was found on adjacent USFS property as well.

From a regulatory perspective the El Dorado County Department of Agriculture wanted to see this pest eradicated as quickly as possible. The challenge became getting all affected entities to be able to quickly react to and treat this pest. Spotted knapweed is an aggressive invader that responds best to chemical treatment due to its ability to reproduce from root fragments, produce 40,000 seeds per plant and its adaptive ability.

Four factors stood in the way of quick implementation of survey and eradication efforts: 1) The Eldorado National Forest had no environmental document in place to allow them to treat with chemicals 2) dense fire and slash debris hid many plants from view, 3) very steep canyon terrain made detection difficult and labor intensive, 4) funding for the eradication efforts was limited and insufficient. El Dorado County Department of Agriculture, as the regulatory agency, spearheaded efforts to bring all parties together and secure the necessary funding to allow for delimitation and treatment. A project partnership was formed that included the Eldorado National Forest, Sierra Pacific Industries, El Dorado County Department of Agriculture and volunteers from the El Dorado Chapter of the Native Plant Society.

Spatial Data

Using Public Domain Remotely Sensed Data to Predict *Taeniatherum caput-medusae* (Medusahead) Infestations, a Case Study from the Central California Foothills.

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Abstract

Wildland managers must deal with biotic invasions in spite of ever more limited resources and in many cases without botanical staff. This project demonstrates the utility of remote sensing to identify invasive plant infestations. These data are freely available from the National Agricultural Information Program. They are aircraft derived 4-band data.

The study site is New Hogan Lake, Calaveras County, California. It is managed for recreation and flood control by the Army Corps of Engineers. The Corps has an aggressive weed removal program. However; they are hampered by a lack of botanical staff. he site is highly disturbed by historic and current mining, dam operations and roads. The grasslands are typical of central California low elevations: they are dominated by Eurasian plants. In this case, the highly invasive medusahead grass, *Taeniatherum caput-medusae*, dominates grasslands of intermediate disturbance.

We used ENVI 4.8 for image processing and ArcGIS 10.0 for mapping, although ArcGIS 10 is capable of all described tasks. Data were acquired from the National Agricultural Information Program combined 2009 growing season.

Field surveys established 214 points greater than one m^2 dominated by the target species. The simple algorithm, the Normalized Difference Vegetative Index, was used. After expert inspection, we concluded that 1) woody plants could be identified to species even if congeners and 2) prediction of medusahead presence is possible. We also used k-means unsupervised ten-class classification. These results support the idea that medusahead is limited to soils with high moisture in June. Medusahead is found in a narrow range of higher late spring soil moisture. Future research includes a supervised classification and implementation of soil-water algorithms to further refine the procedure.

These methods are easily repeatable. While high-end image processing software is prohibitively expensive for agencies and non-profits, free or low cost access is available to students. In this case, the total project software cost was less than $200. Community College GIS programs make good partners. The students benefit from real world conditions and also produce materials for an effective portfolio. Wild lands managers benefit by adding to their weed management tools.

Introduction

In an era of shrinking government support for weed eradication, remote sensing can help fill the gap for restoration programs. Geographic information systems (GIS) built upon field data and the use of vegetative indices can guide both survey and treatment. Many universities and colleges have GIS programs. For example, American River College in Sacramento has GIS work experience slots for 48 students a year. Many GIS students are former professionals working to build new skills. These students can help build your organizational capabilities. The newest version of the most commonly used mapping software, Arc GIS

10 can implement the most common vegetative indices. Vegetative indices literally show us things our eyes cannot see.

Methods

We used ENVI 4.8 (ITT Visual Solutions, 2010) for image processing and ArcGIS 10 (ESRI, 2009) for mapping, although all described tasks can be completed with only ArcGIS 10. Data were obtained from the California Geospatial Clearing House (http://atlas.ca.gov/imagery-Search.html). We used imagery from the United States Department of Agriculture's National Agricultural Information Program (NAIP). These are aircraft derived four-band images (R, G, B and IR) with one meter resolution. NAIP images are acquired during the height of the growing season, typically May to June. California has excellent coverage because of the importance of its agriculture to the nation.

Data were transformed by the application of the Normalized Difference Vegetative Index (NDVI). The algorithm is $NDVI = \frac{Red - IR}{Red + IR}$. The NDVI was developed in the 1970s to predict famines in developing regions (Jensen 1994). Since that time, more than two dozen vegetative indices have come into use. The NDVI works because plants absorb red wavelengths and reflect infrared, both by a better than five to one ratio (Jones and Vaughan 2010). ArcGIS 10 provides NDVI as a built-in transformation.

We surveyed for pure medusahead stands greater than one m^2 and easily found 214 data points. Maps were produced with these data points upon NDVI-transformed NAIP imagery and subjected to expert inspection. Additionally, a ten-class K-means unsupervised classification was performed. Classifications are procedures based upon individual pixel statistics. They simply divide the pixels into groups mechanistically through typical statistical classification procedures.

Results and Discussion

Examination of the NDVI-transformed data allowed identification of woody plants to species. We found that blue oak (*Quercus douglassi*), interior live oak (*Quercus wislizeni*), chamise (*Adenostoma fasciculatum*), and manzanita (*Arctostaphylous viscida*) were easily identifiable in the NDVI image (Figure 1). Their signatures as listed above are going from left to right in the image.

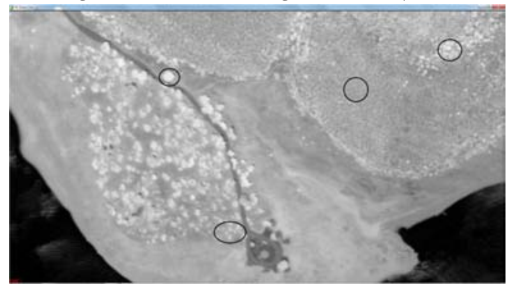

Figure 1

NDVI image of blue oak-chaparral community. From left to right the circled signatures are blue oak (*Quercus douglassi*), interior live oak (Quercus wislizeni), chamise (*Adenostoma fasciculatum*), and manzanita (*Arctostaphylous viscida*).

Medusahead can be controlled with fire and mowing at the soft-seed stage. The study site has a tight urban interface, making fire an unlikely choice. We produced maps with medusahead data points plotted on the NDVI images. Inspection of these images resulted in the following treatment prescriptions:

Mow intermittent watercourses in Acorn campground. Water courses were easily identifiable in the NDVI. The development of this campground created a hydrological impediment that facilitated medusahead infestation by providing the late spring saturated soils it prefers. The hydrological impediment also facilitated an infestation of perennial pepper weed.

Mow intermittently flooded banks. These regularly disturbed areas provide a metapopulation source for upland infestations. Medusahead density is many thousands of stems per meter squared in these areas.

Establish an area to experiment on alternative medusahead treatments. The recommended area is a 12.7 acre site near a monoculture of medusahead.

Examination of classification results found that 100% of our medusahead points fell in only 20% of the classes. This suggests that the further refinement by ground truthing plots could produce a hybrid classification predictive of infested sites. Further iterations may produce a reliable model for medusahead populations at this site (Ray 1994).

Remote sensing capabilities can greatly assist in the identification, treatment and modeling of plant invasions. Recent improvements in mapping software have increased remote sensing capabilities and democratized access to these techniques. We all understand that a proper releve or plot assessment requires a bird's eye view. Remote sensing can add a new layer of information to an even larger bird's eye view than any plot system alone could provide.

This project was conceived as a community college GIS remote sensing class project. Involving student interns in your GIS work has the potential to improve your organization capabilities. Investing time in befriending professors or speaking to classes may find you students to do similar projects.

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Invasive Plant Management in California State Parks

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Abstract

The State Parks Natural Resources Program spends a significant amount of its annual budget on invasive plant management. As a result we have developed a number of innovative programs to manage a wide range of invasive plants throughout the State. Many of the methods employed and lessons learned can be used to inform management elsewhere. Highlighted programs include European beachgrass removal from Del Norte to San Luis Obispo county and riparian restoration in the Central Valley, Monitoring using TNC's Weed Information Management System (WIMS) and early detection-rapid response principles are also key components of the invasive plant management program. Most important among the strategies to continue existing programs in light of budget cuts and park closures has been development of innovative partnerships with other agencies and non-profits. Examples include Weed Management Area and Resource Conservation District partnerships throughout the state.

Introduction to Invasive Plant Management in State Parks

California State Parks (Parks) currently manages 1.5 million acres, with over 280 miles of coastline; 625 miles of lake and river frontage; nearly 15,000 campsites and 3,000 miles of hiking, biking and equestrian trails. The Parks' mission is also diverse: To provide for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources and creating opportunities for high-quality outdoor recreation. Within the Park's umbrella there are 279 classified and unclassified properties, with varied designations including parks, beaches, historic parks, recreation areas, natural reserves and vehicular recreation areas; all designed to address the unique mission. Within these properties there are also natural and cultural preserves and state wilderness areas. By necessity natural resources management in these differing use designations is highly variable. Vegetation management goals, priorities and actions take place at the District level (Figure 1). While weed management is often a priority at the district level, we endeavor to manage for the composite whole of physical and biological processes and to protect natural resources from external impacts, while allowing for managed public

Figure 1

use. Currently there are 70 Parks planned for closure by July 1, 2012 due to budget constraints. Although these parks will be closed to the public in some form, natural resources management, including invasive plant management, will continue, especially in areas with significant previous weed-control investments.

Budgets and District-Level Management

The State Parks Natural Resources Program spends a significant amount of its annual budget on invasive plant management. The budget for Fiscal Year 2010/2011 for ongoing natural resource maintenance was $2.1 million. An additional $2-3 million is allocated for natural resource restoration projects from special bond funding. In the last several years, of the average $4 million annual total spent on natural resource management, nearly $1.5 million was spent on invasive plant management, with about 50% of the $1.5 million used for European beach grass, French and Scotch brooms, yellow starthistle, tamarisk, arundo and cape ivy control.

In marked contrast to the amount of budget allocated, the demonstrated need for ongoing natural resources management (maintaining the status quo) is approximately $16 million. The trend in overall funding for natural resource management has been downward since 2001. Many of the invasive plant infestations in parks today could have been prevented or greatly minimized if the maintenance programs we have today were established and adequately funded over the last 20 years. Staffing is another measure of the health of a program. Currently we have 30 permanent full time Environmental Scientists and 40 to 50 permanent intermittent and seasonal positions that are responsible for almost all the natural resources management, including invasive plant work.

Quantifying the Threat of Invasive Plants on Park Lands

Parks conducted a condition assessment in 2002, which included a survey of districts to determine which weeds were present and which were being managed. From this survey a list was developed of the Parks' twelve most troublesome invasive plants based on impacts to ecosystem processes, community composition and vegetation structure, threatened or endangered plants or sensitive natural communities and ability to spread into

Table 1

The Dirty Dozen

Scientific Name	Common Name
Ailanthus altissima	Tree of Heaven
Amophilla arenaria	European beachgrass
Arundo donax	Giant reed
Carduus pycnocephalus	Italian thistle
Carpobrotus spp.	Ice plant
Centaurea solstitialis	Yellow starthistle
Delairea odorata	Cape ivy
Ehrharta calycina and *E. erecta*	Veldt grasses
Foeniculum vulgare	Wild fennel
Genista monspessulana	French broom
Lepidium latifolium	Perennial pepperweed
Tamarix spp.	Tamarisk

undisturbed areas. These species were nicknamed the "dirty dozen" and are included in Table 1.

Of the 200 park units surveyed, at least one of the "dirty dozen" was reported in 75%, and 40% of the park units contained three or more of the dirty dozen, providing some quantification of the level of infestation of invasive plants throughout the System.

DPR-WIMS

Since 2006 Parks has been monitoring the status of a sub-set of our invasive plant species at a programmatic level. The program is called DPR-WIMS (Weed Information Management System) and is based on a program originally developed by The Nature Conservancy and modified for Park (DPR) use.

Currently there are an estimated 100 different invasive plant species that are considered important threats to Parks lands. Nearly every park is affected by one or more of these species. In total, the number of park unit invasions is over 2,000. The DPR-WIMS mapping effort is designed to provide a barometer of conditions by monitoring eight percent, or 161 of the over 2,000 park unit invasions. In this case an "invasion" is defined as a specific invasive plant location in a management unit of the Parks system. Each of the 161 selected park unit invasions is being reassessed on a three-year cycle. Monitoring includes mapping of the location and assessment of cover/density and distribution within the park unit. The data are then quality controlled and aggregated for each fiscal year and were recently uploaded to Calflora.org. The 30 species being monitored are listed in Table 2.

Non-WIMS Data Collection

Recently we began pulling together non-WIMS weed data sets to determine what additional information is available. Many of these data sets are collected with small Garmin GPS units and are stored on desktop computers at the districts. So far we have received data sets from eight of the 25 districts, representing a number of taxa not included in WIMS: purple loosestrife (*Lythrum salicaria*), pokeweed (*Phytolacca americana*), Saharan mustard (*Brassica tournefortii*), calla lily (*Zantedeschia aethiopica*), mattress vine (*Muehlenbeckia complexa*) and thoroughwort (*Ageratina*

Scientific Name	**Common Name**
Ailanthus altissima	Tree of Heaven
Amophilla arenaria	European beachgrass
Arundo donax	Giant reed
Brassica nigra	Black mustard
Cardaria draba	Hoary cress
Carduus pycnocephalus	Italian thistle
Carpobrotus spp.	Iceplant
Centaurea diffusa	Diffuse knapweed
Centaurea melitensis	Tocalote
Centaurea solstitialis	Yellow starthistle
Cortaderia jubata and *C. selloana*	Jubata/Pampas Grass
Cynara cardunculus	Artichoke thistle
Cytisus scoparius	Scotch broom
Delairea odorata	Cape ivy
Ehrharta calycina and *E. erecta*	Veldt grasses
Foeniculum vulgare	Wild fennel
Genista monspessulana	French broom
Hedera helix	English ivy
Helichrysum petiolare	Licorice-plant
Lepidium latifolium	Perennial pepperweed
Phalaris aquatica	Harding grass
Ricinus communis	Castor bean
Rubus discolor (armeniacus)	Himalayan blackberry
Silybum marianum	Milk thistle
Spartium junceum	Spanish broom
Tamarix spp.	Tamarisk
Ulex europaeus	Gorse
Vinca major	Periwinkle

Table 2

The 30 invasive species that are monitored in State Parks.

adenophora). These data sets are being uploaded to Calflora with the help of Cal-IPC staff and will serve as snapshots for invasive plant distribution in those districts.

Invasive Plant Management Project Examples

As previously mentioned, weed management planning and on-the ground management takes place at the District level, with funds from the state as well as bonds and outside grants. Two examples of important weed management efforts are in coastal dune and Central Valley riparian communities.

In coastal dunes, European beachgrass is one of the top priority invasive plants managed at the State level. Projects are currently on-going from Del Norte to San Luis Obispo counties. This species is an ecosystem changer, forming monocultures, re-orienting dunes and creating habitat unsuitable for sensitive species like Western snowy plover. We often find the need to test different treatments at different locations, based on the situation; there is no one size fits all method based on a variety of environmental, site and even social factors. One excellent example of this approach was accomplished at Little River State Beach located in the North Coast Redwoods District. Three mechanical removal methods were tested and they found the Dozer-Grade method was the most effective. All heavy equipment methods tested were more cost effective than hand removal ($5-6,000 per acre for heavy equipment compared to $30,000 per acre for hand removal) (Transou et al. 2007). Other districts use a combination of fall burning, herbicide application and hand removal in sensitive areas, based on site and project specific constraints. One large 300 acre restoration is in the planning phases at Bodega Dunes, part of the Russian River District. Partners in this project will be Bodega Marine Lab, National Park Service and the local Resource Conservation District.

In the Central Valley, riparian restoration projects are currently underway at Woodson Bridge State Recreation Area and Caswell Memorial State Park. While these projects are much smaller in size than the European beachgrass efforts, they are important given the small amount of native riparian vegetation remaining along the great waterways of central California. The major concern in both areas is edible fig (*Ficus carica*), which is spread by birds and forms dense patches in the understory. Other plants of concern include Tree of Heaven, giant reed, Himalayan blackberry and Osage orange. At Woodson Bridge State Recreation Area a newly aggressive invader is pokeweed (*Phytolacca americana*) which is also forming dense forest understory patches in Gray Lodge Wildlife Area, managed by Department of Fish and Game.

Partnerships

While invasive plant management has been ongoing in Parks for a number of years, we are embarking on new directions in order to target management efforts toward the most damaging pest plants and to apply the latest and most cost-effective control methods. One way to increase effectiveness in this area is partnering with other organizations and weed management groups with similar land management and research missions. In the recent past Parks staff actively participated in Weed Management Areas (WMAs) and were the recipients of small WMA grants for discrete project. For instance, Sacramento WMA previously funded spot treatments of giant reed, pampass grass and other weeds around Lake Natoma. An example of an A-rated weed in a state park is a 280-acre biddy biddy (*Acaena novae-zelandiae*) infestation at Salt Point State Park which would previously have been tracked and managed by California Department of Food and Agriculture biologists.

Current partnerships include participation in an interagency weed-free materials collaboration focusing on developing lists of suppliers for weed-free straw, hay and building materials. We also participated in Cal-IPC's efforts to develop generalized Best Management Practices for land managers and are beginning to work with sister State agencies to share information on weed management issues.

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Using Distribution Information to Understand and Conserve California Flora: Recent Results and Prospects for Further Future Improvement

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Assessment, prioritization, and management of invasive plants depend strongly on comprehensive distribution information. Since the early 1990s, the Calflora database has provided information on wild plants in California for use by scientists, conservationists, and citizens. Originally an 8-character DOS code available only as a file, the emergence and expansion of the World Wide Web has made Calflora's services widely available to nearly 19,000 registered users. Recently, supporting partners (including BAEDN, Cal-IPC, CNPS and NRCS) have invested in data compilation efforts, as well as exciting new tools for mapping and understanding our changing flora. This talk reviews some of these new tools and describes current upcoming partnerships and tools under design. Finally, we present analyses of existing data that are of interest to invasive plant specialists. These analyses include peer-reviewed studies that use the database to understand patterns and mechanisms in invasive plant biology, analyses of overlap between invasive plants and rare plants, and the identification of significant geographic and taxonomic gaps in mapping information.

Climate Change in the Sierra Nevada

Effects of Changing Precipitation Patterns on the Spread of *Bromus Tectorum L.* in the Eastern Sierra Nevada and Implications for Management

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Abstract

Increasing atmospheric accumulation of greenhouse gases will likely entail far-reaching climatic effects, both through increased temperature and changing precipitation intensity and frequency. Much work has been done to predict ecosystem responses to changing temperature; however the effects of changing precipitation patterns are not as well understood. Precipitation may be equally (or more) important in influencing changes in vegetation patterns, particularly in arid ecosystems. Of special concern is the response of invasive plant species, especially at the edge of their invaded range. At high elevation in the eastern Sierra Nevada, the exotic annual grass, *Bromus tectorum* L., is present but has not yet seriously impacted the native plant community, in contrast to lower elevation Great Basin sites where it has completely displaced natives and caused dramatic changes to the fire cycle. Over the past three years, we have used a series of experiments to evaluate how *B. tectorum* might respond to changing snow levels and increased spring rain. We used snow fences to manipulate snow depth and irrigated plots to simulate a shift toward increased spring rain. Snowpack affected the timing of germination and early growth, but had little to no effect on final seedset or biomass. In contrast, spring rain increased *B. tectorum* growth dramatically, with the largest effects occurring on individuals growing in the inter-shrub zone, which implies an increased potential for more frequent fires. Results suggest that *B. tectorum* may become more competitive with a shift from snow to rain events, with the potential to increase its range and have more serious impacts at higher elevation sites. Monitoring and control efforts for *B. tectorum* in a future climate should focus on transportation corridors and invasion-risk areas at elevations above current occurrence.

Introduction

It is well known that increasing concentrations of atmospheric greenhouse gases will alter plant communities via direct effects associated with increased atmospheric CO_2 concentration and indirect effects associated with changing temperature and precipitation patterns (Moser et al. 2009). Much work has evaluated how increased temperature might affect plant communities, while less has been done to predict effects of changing precipitation patterns (Weltzin et al. 2003). However, altered precipitation is likely to have significant effects on plant community composition, particularly in arid or semi-arid ecosystems, where water limits ecological processes and in snow-dependent systems that may experience a shift from snow to rain (Weltzin et al. 2003). The eastern Sierra Nevada, CA, is characterized by being both arid and snow-dependent and is predicted to experience a shift from snow to rain and earlier spring melt timing. Of particular concern in the region is the spread *Bromus tectorum* (cheatgrass), which is currently limited at high elevation but may respond to climate change by shifting range boundaries upward. Since its introduction to the US in the mid 1800s, this species has spread throughout much of the Intermountain West, displacing native shrub and bunchgrass communities, altering fire regimes and transforming the sagebrush steppe ecosystem to annual grasslands (Knapp 1996). Our objective was to determine how shifting snow and rain patterns might affect *Bromus tectorum* spread at high elevation in the eastern Sierra Nevada, CA.

Methods

This study took place in the Inyo National Forest on the eastern slope of the Sierra Nevada, near Mammoth Lakes, CA, at an elevation range of 2,437 to 2,605 meters in the shrub-steppe ecosystem. The climate is Mediterranean and most precipitation falls in the form of snow at an average of 51 to 64 centimeters per year^{-1}.

To measure effects of snow on *B. tectorum*, we used four 30 foot-long fences that were placed perpendicular to the prevailing wind to create zones of increased and decreased snow. Within increased, decreased and ambient snow zones, three replicate plots (25 × 25 cm^2 in size) were set up in each of three dominant microhabitats (*Artemisia tridentata* canopy, or ARTR, *Purshia tridentata* canopy, or PUTR and intershrub space, or INTR). In May and June of 2009 and 2011, we manipulated spring rain by irrigating plots with different size events at different frequencies: 1, 2, and 3 additional 0.8 mm events and three additional 1.6 mm events (totaling 0.8, 1.6, 2.4, and 4.8 mm). We measured *B. tectorum* germination, growth and fecundity in each of the treatments. We used one- and two- way ANOVA tests (JMP, v8) with Tukey comparisons to determine whether differences were statistically significant (= 0.05).

Results and Discussion

Effect of Altered Snowfall

Each of the snow fences created increased snow zones containing roughly twice as much snow with about a two-week delay in melt timing compared to ambient snow zones in both 2010 and 2011, but snowpack was reduced by less than 10% in the decreased zone. Here, we present data from the ambient and increased snow zones only. In 2009, there was not sufficient snow accumulation for the fences to be effective.

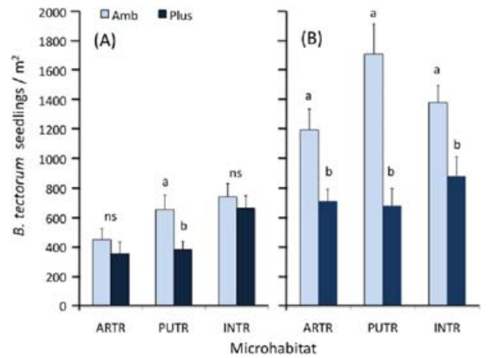

Figure 1

Bromus tectorum germination in increased snow versus ambient snow zones within three microhabitats: under *Artemisia tridentata* shrubs (ARTR), under *Purshia tridentata* shrubs (PUTR) and in intershrub spaces (INTR) in (A) 2010 and (B) 2011. Different letters indicate statistically different means ($\alpha = 0.05$) by snow zone within each microhabitat.

Germination of *Bromus tectorum* was significantly decreased with increased snow in PUTR by 42% in 2010 (Figure 1A) and in all microhabitats in 2011 (by 40% in ARTR, $p = 0.022$; 60% in PUTR, $p < 0.001$; and 36% in INTR, $p = 0.0018$; Figure 1B). However, neither fecundity nor biomass (at the time of harvest) were significantly affected by snow depth. Elevated soil water inputs in the increased snow plots may have led to an increase in seedling growth rates that cancelled out any negative effects of reduced and delayed germination.

Effect of Altered Rain Events

In 2009, supplemental rain (4.8 mm) increased *B. tectorum* biomass and seedset in INTR and PUTR microhabitats, but not in ARTR (Figure 2A). In 2011, however, additional events had no effect on *B. tectorum* biomass in any of the three microhabitats regardless of size or frequency (Figure 2B). The difference in response of *B. tectorum* between the two years may have been due to interannual differences in ambient precipitation type and timing. Although winter precipitation (between October and February) was similar in magnitude between the two years (140 mm in

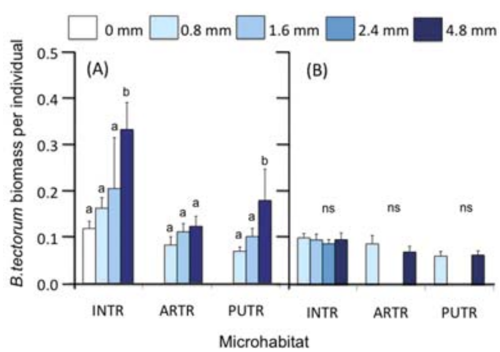

Figure 2

Bromus tectorum biomass in response to increased spring rain simulation treatments (from 0 to 4.8 mm of additional water) within three microhabitats: under *Artemisia tridentata* shrubs (ARTR), under *Purshia tridentata* shrubs (PUTR) and in intershrub spaces (INTR) in (A) 2009 and (B) 2011. Different letters indicate statistically different means ($\alpha = 0.05$) by precipitation treatment within each microhabitat.

2009 and 125 mm in 2011), 2009 experienced little snow accumulation. The larger snowpack in 2011 may have contributed to elevated soil moisture around the time of snowmelt in 2011. In addition, in March and April (during the time of *B. tectorum* germination and most active growth), the area received about 56% more precipitation in 2011 over 2009, likely leading to less water-limitation and the subsequent lack of response to water additions.

Effect of Microhabitat

B. tectorum attained the largest biomass and seed production in INTR microhabitats. This result was surprising since Griffith (2010) documented an effect of facilitation by shrubs. We did find more germination under shrubs, which suggests that shrub habitats may generally support more individuals that experience lower growth rates, while INTR spaces support fewer individuals that grow larger. Perhaps of greater significance was that *B. tectorum* showed the largest response to supplemental water in INTR plots. Increased growth in the inter-shrub spaces can result in increased horizontal fuel continuity and pose a serious fire hazard (Brooks et al. 2005).

Implications for Management

Although uncertainty surrounds predictions of how precipitation might change in future years, managing invasive species based on current occurrence and spread rates would be too simplistic. Instead, managers should be equipped with knowledge of how changing conditions might affect the spread (or retreat) of invasive species in their region so that they can respond quickly to a variety of different scenarios. Our results suggest that changing snow cover may not have much of an effect on *B. tectorum* spread at high elevation, but a shift toward increased spring rain could provide a window of opportunity for it to increase dramatically. Compared to cheatgrass monocultures, *B. tectorum* is currently much less dense at our sites. However, with just a 10 % increase over ambient levels of spring rainfall, biomass tripled in the intershrub space. At a minimum, cheatgrass density and cover should be monitored at high elevation in eastern California and measures should be put in place that minimize the spread of seeds to currently uninvaded areas. During years of abundant spring rainfall, more proactive measures should be used to decrease cheatgrass biomass and cover, eradicate outlier patches that could act as new seed sources and maintain the dominance of native species.

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Predicting the Spread of Invasive Plants in the Sierra Nevada

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Abstract

Cal-IPC developed a "risk mapping" approach to set regional priorities for invasive plant management and develop recommendations for the Sierra Nevada. These recommendations are derived from maps of current distribution for each species combined with projected suitable habitat. We developed models of suitable habitat for 31 invasive plants based on climate conditions in 2010 and 2050. Some of these plants are already widespread, while others are just beginning to move into the Sierra Nevada. We generated the models using Maxent software with GIS datasets

compiled from throughout California and a commonly-used set of 19 bioclimatic variables from Bioclim. These results are based on the A2 emissions scenario. When overlaid with maps of current distribution, suitability maps help show vulnerability to spread. Some species show likely range expansion with climate change, while others contract or shift their ranges. In other cases, the projected range does not change but the level of suitability does. This "risk mapping" approach has been used to determine priorities for eradication, containment and surveillance in the Sierra Nevada. The CalWeedMapper online tool allows natural resource managers to generate maps and management opportunity reports for their area, as well as to explore and update quad data. The system is linked to existing online occurrence databases such as Calflora and the Consortium of California Herbaria. The Sierra Nevada serves as a case study for developing regional recommendations in other parts of California.

Introduction

Land managers need information to help them work most effectively in the face of increasing invasive plants, decreasing budget, and climate change. The Sierra Nevada is likely to be heavily impacted by climate change (PRBO Conservation Science 2011). One potential impact of a warming climate is the expansion of invasive plants into areas previously thought not to have suitable climate. Some invasive plants, such as yellow starthistle (*Centaurea solstitialis*) are spreading into the Sierra Nevada, although it is unknown how much influence climate change has on their spread.

The goal of this project was to support resource managers in setting priorities for effective long-term invasive plant detection and control, including the many projects already in progress in the region and to justify new projects. This project has produced the first statewide maps for many invasive plant species. The approach provides a foundation for regional collaboration and the work on the Sierra Nevada has helped us refine our methodology for recommendations in the rest of the state.

Approximately 100 plants on the Cal-IPC Inventory (Cal-IPC 2006) occur in the Sierra Nevada. We chose a subset of 43 based on discussions with land managers in the region. Using distribution maps and suitability models, we rated these 43 invasive plants for eradication, containment, or surveillance in the entire Sierra Nevada and for each of the 14 Weed Management Areas (WMAs) in the region.

Methods

We developed maps of current distribution and projected suitable range. We mapped distribution by USGS quadrangles: collecting abundance, spread and management data by interviewing local experts as well as compiling GIS datasets from online databases, government agencies and local organizations (Cal-IPC 2011).

To map suitable range, we used Maxent software to predict where a species can survive (Phillips et al. 2006). The software makes statistical predictions based on where the species currently exists combined with data on environmental variables. We used climatic variables since this is the major factor determining suitable range. We modeled suitable range for each species in California using current distribution and climate data for the state. Maxent requires precise geographic locations that represent the range of conditions in which the species grows. For environmental data, we used a set of 19 climatic variables derived from temperature and precipitation measurements. These variables, available at Bioclim (www.worldclim.org), are commonly used in ecological modeling. We based our assessment of future suitability in the year 2050 on the Intergovernmental Panel on Climate Change's A2 emissions scenario, which is widely used for climate change assessments that inform policy decisions.

Mapping climatic suitability for a given plant species is an inexact science. Like any modeling, the results depend upon the assumptions of the particular model and the data used to generate predictions. The maps are based on existing distribution as evidence of the climatic range of the species. We used this approach to map suitable climatic range for 31 of the 43 species studied and defined a change in suitable range where there was ≥10% change. Some species may be able to grow in climates beyond where they currently grow in California, either because they can adapt or because they have not yet been transported to a region with that type of climate.

Results and Discussion

The full results from this project are available in a report released in spring 2011 (Cal-IPC 2011). The underlying data from this project, as well as pdf reports similar in method to this project but for expanded regions such as counties, WMAs, National Parks and National Forests, are available on the CalWeedMapper website (calweedmapper.calflora.org).

The change in area of suitable range for the 31 modeled species varied from a decrease of 14% for Canada thistle (*Cirsium arvense*) to an increase of 40% for Spanish broom (*Spartium junceum*). Fourteen species had an increase in projected suitable range, six species had a decrease, and eleven species had no change. The resulting risk maps overlay current distribution and suitable range to show uninvaded areas that are the most vulnerable to spread. We used the maps to identify three categories of management opportunity:

Surveillance – Surveys to detect new infestations of species thought to be absent

Eradication – Complete removal of an infestation, possible where smaller infestations occur isolated from other infestations

Containment – Limiting spread from larger infested areas. Strategic potential depends on the geography of the infestation, how isolated it is, and the suitability of adjoining areas.

For each species in each WMA, we rated the strategic potential for these management opportunities as high, medium, or low. For each WMA and the region as a whole, we identified species as top priorities for strategic management based on these ratings. Ratings depend on factors such as the impact and invasiveness of the species, whether the particular infestation is spreading, whether the species has a CDFA weed rating and the evaluation of land managers.

Our results complement management efforts already underway in the region and can help in planning future projects. They can also be used to combine new efforts with those that already exist. For example, efforts to contain invasive plant species climbing the foothills from the Central Valley may be able to coordinate with the existing Leading Edge Project that works to prevent the spread of yellow starthistle to higher elevations. Finally, these recommendations and risk maps can be used by region-wide coordinating bodies to establish goals for surveillance, eradication, and containment, in support of early detection. Check us out at calweedmapper.calflora.org!

Acknowledgments

This report would not have been possible without the data and expert knowledge generously provided by hundreds of individuals and organizations involved in Weed Management Areas across the state. Funding was provided by the California Department of Food and Agriculture (American Recovery and Reinvestment Act funds); National Fish and Wildlife Foundation Pulling Together Initiative; Resources Legacy Fund; Richard and Rhoda Goldman Fund; USDA Forest Service State and Private Forestry Program; and USDA Forest Service Special Technology Development Program.

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Climate Change in the Sierra Nevada: Processes, Projections and Adaptation Options

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Earth's natural climate system is characterized by continually changing climates, with climate regimes that oscillate quasi-cyclically at multiple and nested scales from annual to multi-millennial and commonly change abruptly. Under naturally changing climates, plant species in the Sierra Nevada track changes at diverse scales in individualistic manner, with plant communities changing as dominances fluctuate and species ranges shift. The capacity of plant species to adapt to changing natural climates depended historically on their ability to move over the landscape following favorable conditions. The human-dominated climate system, into which earth entered in the mid 20th century, extends beyond relevant historic reference in the nature of control (greenhouse gas emissions), rapid and global rates of directional change (warming) and super-elevated carbon dioxide and methane levels. Modeled future climates for the Sierra Nevada anticipate continuing trajectories of climate and greenhouse gases even if greenhouse gas emissions are reduced soon. The extensive human footprint of land use severely restricts the capacity of plant species to adapt to the rapid changes. General principles for conservation and biodiversity protection under anthropogenic climate change are rapidly being developed and implemented. I summarize a strategic framework toward adaptation as a toolbox approach. Conceptual tools to be mixed and combined include the "5Rs": Reduce greenhouse gas emissions; Resist change; create resilience to change; anticipate and proactively enable response to change and realign ecosystems that are far out of natural variability. Priority-setting becomes more critical than before. Taking this framework to practice, I outline a process for evaluating needs and decision-making using case-study examples from the Sierra Nevada and similar mountain regions.

Pesticide Laws and Regulations

Records and Storage Requirements for Pesticide Applicators

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Pesticide laws and regulations for pesticide applicators topics covered will include licensing and registration requirements, pesticide records and use reporting, hazard communication and notification requirements, medical supervision, worker safety and training requirements, respiratory protection programs, proper pesticide storage and container disposal.

The Pesticide Use Monitoring Inspection: What Every Applicator Needs to Know

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Laws and regulations for pesticide applicators highlighting the inspection process. Learn what to expect if you are inspected and how to deal with any issues that may arise in the field. Topics covered will include; work requirements, the pesticide label and safety requirements, protection of persons, animals and property, personal protective equipment, safe container transport, mixing and loading procedures, accurate measurement, field postings, safe equipment, backflow prevention, wellhead protection and enforcement procedures.

Best Management Practices Establishing a Closed Chain of Custody for Herbicide Use in the Utility Vegetation Management Industry and Laws and Regulations for Utility Vegetation Managers

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An outline of laws and regulations pertaining to Utility Vegetation Management will be reviewed with a detailed discussion on how the closed chain of custody can help manage reporting for utility vegetation managers. The Utility Arborist Association (UAA) has established a new Best Management Practices (BMP), focusing on a closed system using returnable, reusable containers. The new BMP defines an end-to-end strategy for managing the herbicide chain of custody from manufacturer to custom blender, distributor, utility owner and applicator and improves compliance with use reporting, safe handling and environmental protection requirements in utility vegetation management.

Recent Court Orders and Injunctions for the Protection of Endangered Species

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Recent court injunctions to protect endangered species have placed use-restrictions on a large number of commonly used herbicides in California. The 2004 injunction and court order for Salmonid protection imposed a consultation schedule between US EPA and the National Marine Fisheries Service (NMFS). In the case of pesticide registrations by US EPA, the consultation centers on the potential effects of 37 pesticide active ingredients on Pacific Salmon and Steelhead. Under the injunction, there are exemptions provided to vector control and invasive weed programs. However, once consultation is completed, for each active ingredient NMFS issues a Biological Opinion with a series of recommendations/requirements known as Reasonable and Prudent Alternatives (RPA). US EPA is expected to incorporate these RPAs into Federal Insecticide, Fungicide, and Rodenticide Act – enforceable county bulletins, to be followed by all pesticide applicators. The latest drafts of the county bulletins provided for comment to Department of Pesticide Regulation and county agriculture departments don't provide exemptions to invasive weed programs. The implications on herbicide applications by weed control agencies will be highlighted, along with earlier court injunctions and informational resources for complying with injunction requirements.

Management and Restoration

Tipping the Balance: Using Natives to Combat Weeds and Promote Ecological Resilience of Riparian Restoration

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Due to the construction of dams and levees throughout the Central Valley for agricultural and urban development purposes, current ecological conditions on most of its floodplains do not favor the establishment of native woody or herbaceous species. Dams and levees have altered the natural hydrology (e.g. flood frequency, duration and amplitude) and geomorphology (e.g. sediment transport, bank erosion and river meander) to which native riparian vegetation is adapted and reliant upon for reproduction and successful establishment. Because of these alterations, native vegetation is frequently outcompeted by aggressive invasive weeds. Restoration projects implemented on the Sacramento River over the past few decades have established approximately 8,000 acres, to date, of riparian forests with native woody species. Frequently, however the herbaceous understory layer is dominated by annual grasses or other weeds including yellow-starthistle or milk thistle.

Large scale restoration projects (up to 800 acres) undertaken by River Partners within the last decade have been targeted at increasing overall biodiversity and habitat structure for wildlife usage. Our goal is also to combat the establishment of non-native invasive species. All of these objectives have been achieved through an aggressive approach of understory weed management and the establishment of an herbaceous layer consisting of perennial natives. Through our experimentation, River Partners has been successful at germinating and establishing several native herbaceous species in the field, including mugwort (*Artemisia douglasiana*), gumplant (*Grindelia comporum*), telegraph weed (*Heterotheca grandifolia*), evening primrose (*Euthamia occidentalis*), creeping wild rye (*Lymus triticoides*) and blue wild rye (*Elymus glaucus*), to name a few. We use an approach that combines modern day agricultural equipment and techniques along with up-to-date scientific knowledge and adaptive management practices. With this combination, we are able to 1) collect and process native seed from remnant vegetation within a project site, or as close to a the site as possible, in order to ensure the genetic adaptation of the local ecotype, 2) plant and establish large acreages with multiple native understory species and 3) effectively control non-native invasive weeds throughout the project sites.

For example, our approach on the San Joaquin River National Wildlife Refuge (SJRNWR) has been during the first project year, install rows of woody trees and shrubs, followed by aggressive weed control during the first two growing seasons. A sterile seedbed approach is employed to the aisles between rows, where repeated discing and irrigation events flush the existing seed bank of non-native and invasive species. Hand labor used to remove weeds occurring on planting rows where discing or herbicide use would damage planted woody species occurs routinely throughout the growing season to ensure seed set does not occur. This reduces competition for native grasses and forbs that are installed at the end of the second growing season by broadcast and drill seeding. The seeded native understory will receive irrigation for one year and may be mowed if dense weeds are noted in the field. Mowing events are timed to ensure that non-native weeds do not go to seed. To help ensure successful establishment of a robust herbaceous understory, River Partners collects seeds from local ecotypes, found either on the SJRNWR or nearby in the watershed. This approach has resulted in a dense cover of native herbs: 65% and 71% absolute cover of native herbaceous species on two fields surveyed in 2010, typical of many of our projects in this region and more recent projects implemented on the Sacramento River as well.

This method of understory establishment has been employed by River Partners since 2004. Since then, we have restored approximately 1,700 acres of riparian habitat on the SJRNWR alone. This approach has not only been successful at combating non-native invasive weeds, the planted understories have also been resilient to disturbances including fires and long-duration flood events. Future monitoring efforts are being designed in order to assess the long-term effectiveness of weed control from these understory plantings.

Evaluating Distribution and Prevalence of Non-native Vegetation Percent Cover in a Southern California Wetland and its Application to Inform Habitat Restoration and Non-native Vegetation Control.

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Abstract

The Ballona Wetland Ecological Reserve (BWER) in Los Angeles, California has been impacted by many anthropogenic, hydrologic and geomorphic modifications and has been subject to non-native vegetation invasions and extensive habitat degradation. The goal of this paper is to present the preliminary findings, including 1) identification of habitats with high non-native species presence, 2) determination of prevalence of native and non-native vegetation percent cover in each habitat type, 3) use of percent cover to define dominant species in each habitat and 4) determination of correlations between prevalence of non-native vegetation percent cover and other parameters collected on a subset of transect (e.g., elevation, inundation).

Vegetation was assessed using a stratified random sampling method. Habitat types were assessed to vegetation alliance level while species level data and percent cover were collected on each transect. Elevation and inundation information was collected on a subset of the transects used for vegetation surveys. Upland habitats were found to be dominated by non-native vegetation percent cover and to contain higher non-native species diversity and presence. The dominant species in these habitats were *Carpobrotus* spp., *Bromus diandrus, Brassica nigra* and *Chrysanthamum coronarium*. The dominant species in native vegetation dominated habitats were *Cressa truxillensis, Jaumea carnosa* and *Salicornia virginica*. Percent native cover was found to be negatively correlated with elevation (r = -0.558); percent non-native cover was found to be positively correlated with elevation (r = 0.589). Inundated areas had lower non-native cover and higher native cover.

These results will inform the restoration alternatives and aide in non-native vegetation control and habitat restoration. Identifying conditions favorable to non-native vegetation cover will also assist in forecasting possible changes in non-native percent cover resulting from climate change, sea-level rise and anthropogenic stressors.

Introduction

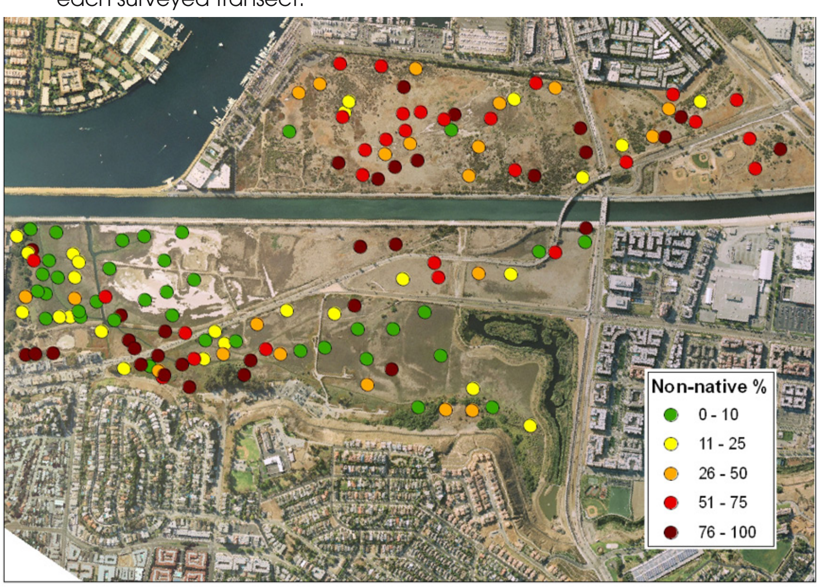
The 600 acre Ballona Wetlands Ecological Reserve (BWER) represents the largest opportunity for coastal wetland restoration in Los Angeles County; it is one of approximately 40 coastal wetlands along the 1,045 miles of the Southern California coast between Point Conception and Mexico. Over the past century, the hydrology, geomorphology, pedology and connectivity of the site have been altered, resulting in extensive habitat modifications. The BWER has been the disposal site for dredge spoils and fill from the channelization of Ballona Creek, the dredging of Marina del Rey, the construction of the Pacific Electric Railroad and the establishment of oil derricks/platforms, among others. The original marsh surface of over half the wetlands was buried beneath this fill (upwards of 20 feet in some areas). This led to an increase in elevation and changes in drainage due to altered grain size, permeability, ponding capacity, slope and grading and soil alkalinity.

The water inflows to the BWER (Ballona Creek, Marina del Rey, urban runoff, stormwater and groundwater) have all been subject to anthropogenic variations in quantity, frequency, velocity and salinity. The construction of the Ballona Creek levees in 1932 effectively isolated the BWER from regular tidal influence. Restricted tidal flows are present in a small portion of the BWER through a self-regulating tide gate into steep tidal channels.

Physical conditions, including elevation and inundation, have been assessed in previous studies as important characteristics that help to define the vegetative composition and habitat delineations (Sanderson et al. 2001, Morzaria-Luna et al 2004, Noe and Zedler 2000). Building on these studies, this paper seeks to assess the habitat types of the BWER based on native/non-native vegetative cover and correlations with elevation and inundation.

Figure 1

Average percent cover of non-native vegetation on each surveyed transect.



Methods

Site-specific sampling protocols for the project included random quadrats along transects, similar to Zedler (2001). Overall, 144 vegetation transects were surveyed including 70 in the salt marsh habitat types and 74 in non-salt marsh habitat types during the season of peak biomass for each habitat type. Transects were randomly allocated within each habitat type based on preliminary plant community mapping of the BWER (DFG 2007).

Elevation surveys were conducted using U.S. Geological Survey and other published benchmarks and included measurements every five meters along each transect, with a total of five elevation points per transect. Benchmark leveling (vertical control survey) was measured using a Trimble GPS, tilting level, a tripod and No. 1 SK rod (ft), 10ths and 100ths.

Data were analyzed to determine significance between-habitat relationships (ANOVA) and physical parameter relationships to vegetation cover (correlations) ($\alpha < 0.05$). Paired transects were analyzed to determine the effect of inundation on nativity (2-way ANOVA).

Results and Discussion

Habitat differences based on plant nativity and species composition were found to be significant. Transect results from the first year surveys (Figure 1) indicated percent cover dominated by non-native plant species in the upland grassland and scrub habitats and higher percent cover of native species within the low marsh, mid marsh, high marsh, seasonal wetland, salt pan and brackish marsh. The low salt marsh habitat type had the highest percent cover (average ± standard error) of native species at 91.0 ± 5.2% (Figure 2). The mid and high salt marsh and the seasonal wetlands had similar high levels of native cover (60.4 ± 12.9%, 62.3 ± 9.1%, and 60.6 ± 8.5%, respectively). The dune, grassland and scrub habitats had higher non-native species average percent cover than native (45.0 ± 1.1%, 77.1 ± 1.1%, and 58.8 ± 1.1%, respectively).

The most prevalent non-native species in the upland habitats included iceplant (*C. edulis*), black

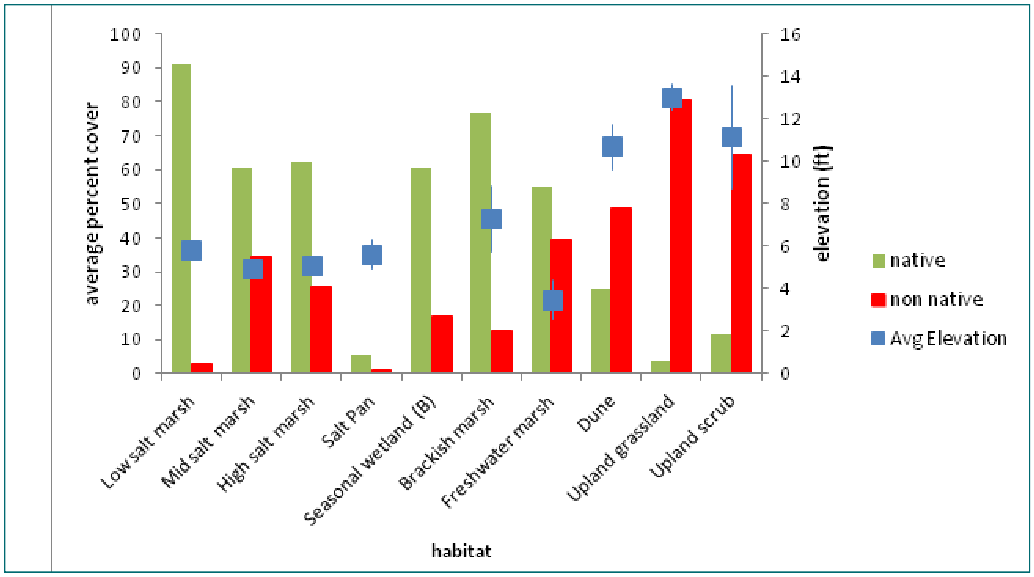


Figure 2

Non-native percent cover and average elevation by habitat type

mustard (*B. nigra*), ripgut chess (*B. diandrus*), and crown daisy (*C. coronarium*), all of which are invasive (Cal-IPC 2006). The most prevalent native species in the tidal marsh habitats included common pickleweed (*S. virginica*), alkali weed (*C. truxillensis*), *J. carnosa* and Parish's pickleweed (*S. subterminalis*). The brackish marsh habitat was dominated by native *Juncus* spp. and *Scirpus* spp. and the freshwater marsh was dominated by non-native *Carpobrotus* spp.

As hypothesized, physical characteristics were found to be a significant factor in the determination of plant cover nativity. Percent native cover was found to be negatively correlated with elevation ($r = -0.558$); percent non-native cover was found to be positively correlated with elevation ($r = 0.589$). Inundated transects had significantly lower non-native cover that non-inundated transects (ANOVA, $F = 7.03$, $p < 0.05$) and significantly higher native cover (ANOVA, $F = 10.1$, $p < 0.05$). A significant elevation difference existed between habitat types (ANOVA $F = 10.7$, $p < 0.001$; Figure 2); however, several habitats were statistically similar when evaluated for elevation (i.e., low marsh, mid marsh, high marsh, salt pan and seasonal wetland). Anomalous physical conditions were identified in several habitat types. For example, the average elevation of the low salt marsh was slightly higher than that of the mid salt marsh and portions of the low salt marsh habitat did not receive inundation on even the highest spring tides.

Identifying habitats within the BWER with high non-native vegetation cover has helped identify characteristics favorable to non-native species. The 'upland habitats' likely contain the highest cover of invasives due to a combination of shared physical characteristics (e.g., non-native soils, quick drainage, no tidality). The prolonged saturation of soils through tidal influence, and thus saline inputs, are all but eliminated. Native soils and seed banks were buried by fill, allowing invasive plants to gain a foothold. By identifying these conditions, a systemic solution to non-native invasive species control can be defined and integrated with site-wide restoration alternatives. Controlling invasive species in upland habitats will remove a source and limit dispersal of invasive plant species into traditional marsh habitats.

The correlations between elevation and vegetation cover corroborate the proposed construction of functional elevational gradients and reconnection to a tidal system as a means to increase native plant species and, by extension, those animal species which rely on them by. Restoration recommendations based on these surveys include reducing the invasive plant seed bank while reintroducing tidal influence to the portions of the site that are currently restricted. Overall, the muted tidal system appears to be reducing the nativity and ecological potential of a fully tidal wetland system. Future surveys should be conducted to assess the specific differences in soil quality and hydrology throughout the site.

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Effectiveness of Aquatic Invasive Plant Control in Emerald Bay, Lake Tahoe, California

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Abstract

Emerald Bay is a unique, high profile attraction in the Lake Tahoe basin and is a primary destination for photographers, boaters, campers, hikers and other recreationists. The establishment of invasive aquatic plant species in Emerald Bay is of great concern to a large variety of interests due to the adverse effects these plants can have on near shore ecology and visitor enjoyment. A cooperative effort among management and regulatory agencies, scientists and professional divers was initiated to combat invasive aquatic plants in Emerald Bay after dramatic expansion of Eurasian watermilfoil (*Myriophyllum spicatum*) was discovered in 2003. A series of small-scale treatments were deployed in Emerald Bay between 2005 and 2009, but the infestations continued to persist and expand. In 2010 we pursued a combination of two treatment methods, benthic barriers and diver-assisted suction removal, over an entire infestation site in a strategic attempt to attain control and eventually complete removal of a discreet infestation area. By combining methods, a large continuous area was treated more efficiently, with benthic barriers treating the main area of the infestation and diver-assisted suction removal specifically targeting hard to reach areas, margins and gaps in the barriers and sparsely infested patches. This combination of treatment methods maximized the cost/benefit ratio and one method reinforced the effectiveness of the other. Approximately one-third of the total infested substrate in Emerald Bay was reduced to a level that can be maintained with small scale annual retreatments as post-project effectiveness monitoring detected zero plants in the sample plots with an estimated 95% reduction in overall plant cover within the discreet infestation.

Introduction

Emerald Bay is one of the highlights of any visit to Lake Tahoe. The establishment of invasive aquatic plant species in Emerald Bay has the potential to alter the character of this unique area. Potential impacts from invasive plant infestations include localized degradation in water quality, alteration of the substrate allowing further expansion of the infestation, changes in habitat conditions that favor other non-native species, adverse swimming conditions, negative impacts on recreational boating and increasing amounts of plant material fouling beaches (Eiswerth et al. 2000). Many of these potential impacts could be more substantial in Emerald Bay compared to Lake Tahoe proper because of the high recreation use and closed basin condition.

The invasive aquatic plant, Eurasian watermilfoil (*Myriophyllum spicatum*; EWM), may have been in Lake Tahoe as early as the 1960's in the Tahoe Keys (Donaldson and Johnson 2009). In 2000, a few plants were documented adjacent to the outlet of Eagle Creek. By 2003, this infestation had expanded to a total area of approximately one acre (Anderson and Spencer 2006).

A cooperative effort among management and regulatory agencies, scientists,and professional divers was initiated to combat the EWM invasion in Emerald Bay after the dramatic expansion was discovered. A series of small-scale treatments were deployed between 2005 and 2009, but the infestation continued to persist and grow. Underwater monitoring transects established by California State Parks documented this persistence. In 2010 we implemented a combination of treatment methods in a strategic attempt to attain control of a single, discrete infestation area. This paper describes the 2010 project and initial results.

Methods

Emerald Bay is an embayment formed through glacial activity in the southwest corner of Lake Tahoe, with a narrow inlet separating the bay from the lake. Three distinct areas infested by EWM were present in the western end of Emerald Bay in 2010 (Figure 1), covering approximately three acres.

Past control efforts employed one of two treatment methods: diver-assisted suction removal or benthic barriers. Diver-assisted suction removal involved divers working underwater to hand pull weeds and place them into a suction hose that transfers the plant into a container positioned on a boat. The weeds are captured in the screened-in container for disposal. Benthic barrier treatment consists of placing sections of gas permeable plastic over the top of the weeds to exclude all light. The small-scale treatment efforts implemented between 2005 and 2009 did not attempt to combine treatment methods in any one discreet location, but largely deployed them independent of each other.

In 2010, efforts were focused on the Vikingsholm infestation (Figure 1) because the risk of spread was highest in this location due to higher boat traffic. A combination of both benthic barrier and diver-assisted suction removal methods were used to treat the entire infestation. Previously established underwater transect surveys measuring plant density and percent cover were continued in order to monitor treatment effectiveness.

Results and Discussion

Monitoring of previous EWM control efforts in Emerald Bay established that a patchy and small-scale effort is not sufficient to contain existing infestations or control the spread of EWM. This finding is consistent with past EWM research on recolonization of treated areas that indicated that treated areas adjacent to untreated infestations are prone to rapid recolonization, while treated areas far from untreated infestations are recolonized at a much slower rate (Eichler et al. 1995). In spite of previous small-scale efforts, EWM infestations in Emerald Bay had grown to approximately three acres by early 2010.

During 2010, approximately 0.2 acres of benthic barrier deployment in May was followed by diver-

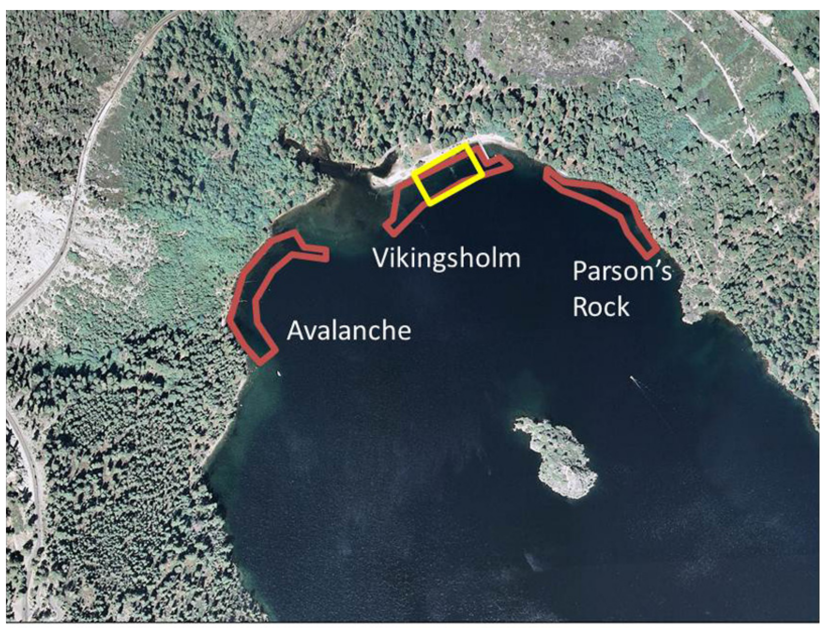

Figure 1

Delineation of approximate infestation areas, spring 2010. The red lines indicate infestation boundaries. The yellow line indicates the approximate area of bottom barrier deployment.

assisted suction removal throughout the summer. The EWM was still alive under the barriers during a late June dive, indicating that barriers need to be left in place for greater than six weeks under growing conditions present during 2010. All EWM under the benthic barriers were dead after removal in mid-September suggesting that four months was an adequate amount of time to kill EWM.

The diver-assisted suction removal was estimated to have removed over 95% of the remaining EWM plants in the Vikingsholm infestation that were not covered by benthic barriers for a total estimate of greater than 95% removal of approximately one acre of EWM. Transect surveys conducted after all treatment work found no plants in the Vikingsholm infestation (Figure 2), supporting the qualitative observations.

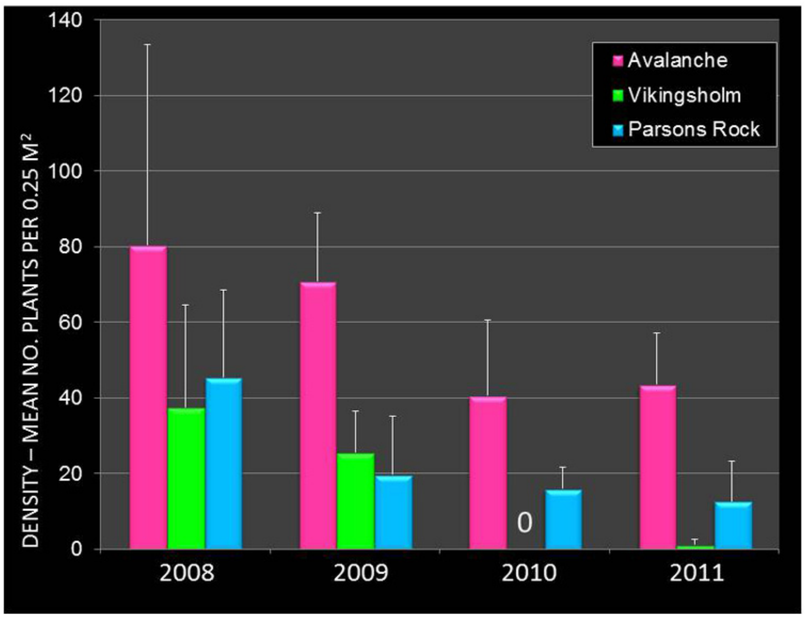

Figure 2

EWM at the three infestation sites in Emerald Bay expressed as plants per 0.25 m^2. The white lines above each bar indicate one standard deviation. Post-project surveys in the fall of 2010 documented complete removal of EWM plants along the Vikingsholm monitoring transect.

This strategic effort to remove all plants in a discrete infestation with multiple treatment methods yielded promising initial success. By combining methods, a large continuous area was treated more efficiently, with benthic barriers treating the main area of the infestation and diver-assisted suction removal specifically targeting hard to reach areas, margins and gaps in the barriers and sparsely infested areas. This combination of treatment methods maximized the cost/benefit ratio, and one method reinforced the effectiveness of the other.

The Vikingsholm project area will require regular maintenance level retreatment efforts into the future to remove any EWM plants that may become established from fragments coming from the other two infestations in Emerald Bay or from fragments brought into the bay on boats and currents. Strategic EWM removal in the other two infestation areas in Emerald Bay in the near future would substantially reduce the rate of recolonization in the project area. A successful control program in Emerald Bay could be very productive in garnering public support and sustaining the long term goal of invasive aquatic plant control in Lake Tahoe.

Acknowledgements

This project was a cooperative effort among management and regulatory agencies, scientists and professional divers. Particular thanks go to Marion Wittmann, Brant Allen, Doug Freeland, Nicole Cartwright, Rita Whitney, Patrick Stone and the California State Parks Natural Resources Crew. Staff time and funding for this project were provided by many sources including a grant from the US Bureau of Reclamation.

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Road(sides) to Recovery: Containing the Spread of Invasive Plants by Implementing a Comprehensive Roadside Weed Removal Initiative on Catalina Island

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Abstract

It is well documented that invasive plant propagules are easily dispersed by human-made transportation routes, such as dirt roads. Disturbance caused by routine maintenance and the distribution potential afforded by resource users creates an ideal situation for weed establishment and dispersal. The Catalina Island Conservancy (CIC) has taken an aggressive stance against this threat by establishing and maintaining a 200-foot weed-free buffer zone along all roads (220 miles) on CIC property and a 20-foot buffer along foot trails (37 miles). Since August 2009, the roadside project has treated 17 species of invasive plants in the entire 10,155 acre project area. Major challenges encountered include large populations of weeds, buffer zones not aligning with geographic boundaries, developing simple protocols for planning complex project areas and maintaining high output despite a high crew turnover rate. Solutions to these challenges are discussed herein.

Introduction

The Catalina Habitat Improvement and Restoration Program (CHIRP) is responsible for mapping, prioritizing, removing and monitoring the island's 200+ introduced plant species. CHIRP began in 2003 by creating an island-wide map of introduced species and assigning each species a management priority rating. Highly invasive and limited distribution species were slated for eradication and targeted immediately. Currently, 34 plant species are scheduled for eradication and all known populations are treated each year.

The success of the eradication program has allowed CHIRP to expand its focus to the more difficult arena of removing more widely distributed weeds. CHIRP has addressed these species by removing them when they occur near roads and trails. Human transportation routes (especially frequently graded dirt roads) are well documented dispersal routes for invasive plant propagules (Spellerberg 1998). Each grading event can move invasive plant seed up to 50 meters and up to 250 meters (Rauschert 2011). Weed seeds can also become stuck to vehicles in mud during rainy periods and transported great distances (Zwaenepoel 2006). Multiple gradings per year results in weed spread that is many times the natural dispersal distance of most species. Since dispersal potential is much higher along roads, roadside weed populations are more likely to represent satellite populations (Figure 1). If these are removed, large areas can be kept free of many invasive plants. The enhanced dispersal potential and high

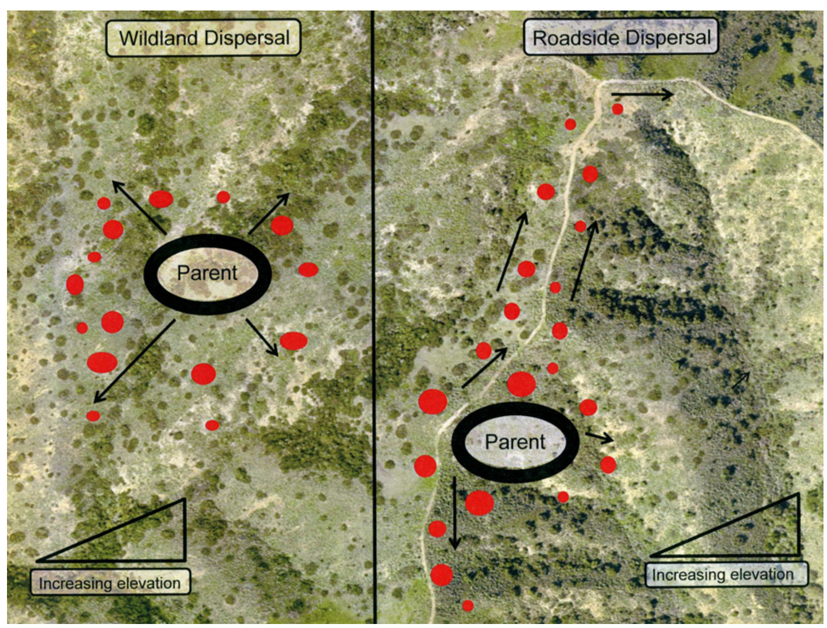


Figure 1

number of satellite populations elevate roadside invasive plant removal to top priority for CHIRP.

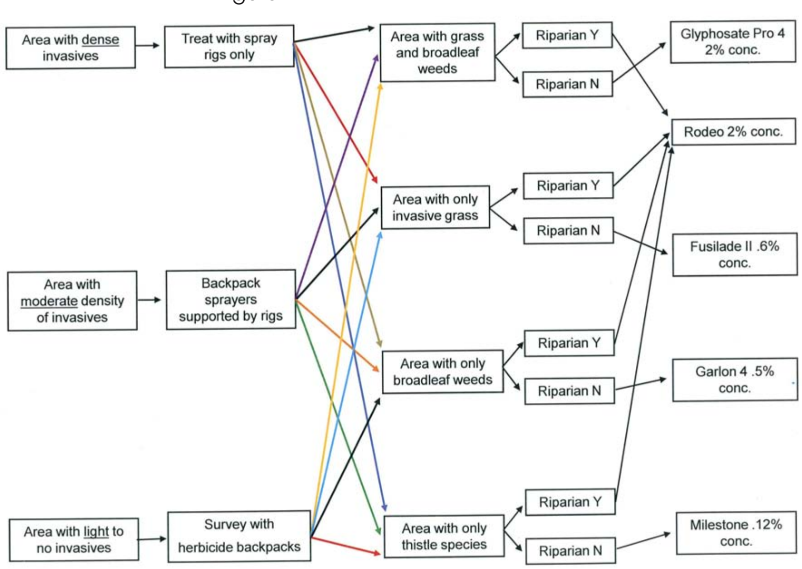
The land mass of Catalina Island is approximately 48,000 acres in size. Its terrain is extremely rugged and has resulted in the creation of 81 watersheds and 24 sub-watersheds (105 Watershed Management Units (WMU)). This makes the average WMU a manageable 460 acres. By creating a weed-free buffer along roads and trails, we greatly reduce (or even eliminate) the connectivity of weed propagules between watersheds. At that point, it is possible to treat each watershed as its own discrete eradication project.

CHIRP received funds from USFWS and NRCS in 2009 to begin removing invasive plants from a 200-foot buffer zone along all 220 miles of roads on the island (10,155 acres). The roadside project operates from January through June with a dedicated six-person crew with support from regular CHIRP staff. The crew is provided by American Conservation Experience (ACE) and is composed of one permanent supervisor and five one-month volunteers. The roadside crew utilizes three truck-mounted spray rigs, backpack sprayers and hand tools to treat as much of the total 220 miles of road as possible (160-190 miles per year). The primary target species are fennel (*Foeniculum vulgare*) and Harding grass (*Phalaris aquatica*). However, the roadside project also removes fourteen other species.

Methods

Roads were initially surveyed in early spring of 2009 for presence/absence of the two primary species, fennel and Harding grass. This was accomplished using vehicle surveys. Initial treatments were planned on the basis of this rough map. During the course of the project, this "war" map has become much more detailed and our understanding of the spatial distribution of target species has improved. Areas are now assigned a light, medium, or heavy rating for fennel and Harding grass separately. Light rating is defined as weeds existing within the 200-foot treatment buffer and not outside of it for at least 200 feet; or no weeds present. Medium is defined as significant weed populations existing inside the treatment buffer and scattered outside the weed free buffer. Heavy rating is reserved for large weed populations that usually exist both inside and outside the 200-foot buffer.

Figure 2



The treatment strategy is tailored to the specific conditions of each project site. Figure 2 shows the decision chain that is used to plan each treatment area. Areas with a light rating for priority weeds receive the most rigorous treatment and are managed as eradication projects. Medium and heavy project areas are managed for reduction and control, respectively, with the goal of moving their classification to a less infested rating. This strategy treats the expanding edge of weed populations as top priority and prevents crews from spending too much time in project areas that are overrun with weeds.

Invasive plant removal is performed using both manual and chemical methods. Manual removal is performed using drain spades and pulaskis to cut fennel roots where the crown meets the taproot. When used properly, this method results in minimal soil disturbance. This method of removal is excruciatingly labor intensive in dense populations and is therefore not attempted in moderate and heavy areas. Manual treatments resulted in near 100% kill rates, however seedling recruitment was much greater in areas treated manually the previous year. Crews mow fennel as a site prep for the spring herbicide treatment season. This is most effective in November and December and is accomplished using Stihl FS 110 weed eaters equipped with brush knives. Mowing near the end of the dry season resulted in safer and more effective chemical control the following spring. Mowed plants grow back much thicker and with greater leaf surface area for herbicide uptake. Plants are also significantly shorter, resulting in safer herbicide application. Herbicide treatments consist of foliar application of Glphosate Pro IV, Rodeo, Garlon 4, Milestone and Fusilade II. Herbicides are applied using truck-mounted spray rigs and backpacks. Treatment with herbicides has resulted in significantly more efficient control when compared with manual removal efforts. Injury to non-target plants is reduced by using the most selective herbicide and lowest possible application rates appropriate for each project site.

Each month, a new set of crew members must be trained on species identification, herbicide safety and survey/treatment/safety protocols. Working along roadsides and with herbicides present many safety challenges that must be addressed. The high rate of personnel turnover has made an effective training program of the utmost importance. Each crew begins their one month spike with a full day of orientation with CHIRP staff. Orientation consists of training in island ecology, invasive species impacts and identification and safety training. The roadside crew supervisor and CHIRP personnel closely monitor each new crew member's performance to ensure responsible use of herbicides.

Discussion

As with any weed removal effort, return on investment is greatest when treating satellite or other isolated plant populations (Radosevich, 2003). This corresponds with our light classification and approximately 100 of the total 220 miles of road on the island fall under this category. Removing as close as possible to 100% of the priority weeds in these areas is the primary project objective. Each passing treatment season has required an adaptation in survey/treatment methods to meet this primary objective. The project has evolved from "how do we kill as many weeds as possible in the shortest amount of time?" to "how do we kill 100% of the weeds in top priority areas and still work in medium and heavy areas as well?"

Initial treatments in most cases were performed with much less attention to detail than follow up treatments. This resulted in the highest number of plants removed and the creation of weed-infested fragments within treatment areas. Subsequent treatments revisited dense areas and chipped away at small infestations that were previously missed. After several rounds of treatment, mature individuals are usually only found in hazardous areas such as dense cactus, poison oak, or cliff faces. These areas pose unique challenges and it is up to the individual crew leader's ingenuity to address these challenges.

The roadside treatment project is tailored to the unique conditions of Catalina Island; however the appropriate combination of planning, funding and implementation should result in an effective roadside weed removal program in any setting.

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Sustainable Solutions to Cross Restoration Thresholds and Build Ecological Resilience: Orange County Invasive Management (OCIM) Project

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Sustainable restoration of invaded, degraded lands has had mixed success due to numerous factors including low rainfall, soil compaction, poor water infiltration and exotic plant competition. In order to efficiently allocate a limited land management budget, land managers must weigh various ecological constraints and long-term recovery in planning for invasive management, recognizing tradeoffs among outcomes and imposed by economic constraints that vary across the landscape. The objective of this study was to assess the effectiveness of differing restoration intensities and identify possible environmental and anthropogenic variables that may be used as predictors of restoration success. These predictor variables would then be used to create a web-based tool to aid managers in making more informed restoration and exotic plant control decisions based on site environmental and historical land used variables. We compared across environmental and anthropogenic gradients of soil type, aspect, slope, elevation, vegetation percent cover, land-use history and exotic plant management history (no action-control, passive, active, intermediate) across the Central and Coastal Reserves of Orange County, CA. Collaboration with land managers led to sampling of 131 sites and a clear identification of land use issues and management needs that will be incorporated into the planned web-based tool. Preliminary vegetation analysis indicates that all levels of management intensity lead to higher native cover as compared to no action; whereas, native plant richness was higher in active and intermediate restorations only. Target exotic plant species (*Brassica nigra* and *Cynara cardunculus*) were effectively reduced by all management intensities. However, only the intermediate and active levels of restoration led to overall reduction of exotic plant cover. These preliminary results indicate that restoration efforts at any intensity can lead to increases in the native plant community, but more intense restoration efforts will be necessary to increase native richness and reduce overall exotic plant invasion.

Prioritizing and Promoting Region-wide Invasive Plant Management: A Report on Successes from the Bay Area Early Detection Network

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This talk reports on outcome of work conducted by the Bay Area Early Detection Network (BAEDN). BAEDN partners have built an Early Detection / Rapid Response (EDRR) system to protect the entire nine county San Francisco Bay Area, which has recently completed its second field season. In the first season staff downloaded thousands of unique plant occurrence reports from the Calflora database, and evaluated distribution of potential target species in the Bay Area. Weed risk assessment identified species known to have high impacts but not yet widespread in our area. Occurrences of 73 target species were prioritized for treatment using the WHIPPET model, which ranks infestations for elimination based on a number of characteristics. Staff worked through >800 infestations, contacting land managers to verify status and encourage rapid response. The result is that one third of infestations were under treatment as of September 2010. In this second

field season, BAEDN provided funding to partners and contractors to ensure treatment of these infestations. In this talk, we review the results of this effort to promote and subsidize region-wide EDRR and we summarize important lessons learned. We also present results of recent efforts to prioritize species and occurrences of Bay Area wetlands and discuss planned assessments that will expand effective coordination to protect these valuable and sensitive habitats.

Examining Broader Impacts

Designing Wildlife Avoidance into Invasive Species Control Projects: A Case Study

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Empirical data and conventional wisdom states that invasive plants provide either degraded habitat or no habitat value for native wildlife. As more native habitat is lost, wildlife has increasingly become adapted to using non-natives for cover, nesting and other important functions. Invasive species control often overlooks the need to perform adequate pre-project surveys and incorporate wildlife avoidance into implementation plans.

Projects that impact listed species are not usually an issue as the entire project must be designed with the listed species in mind. These projects may employ trained biologists, incorporate Best Management Practices and have avoidance, mitigation and monitoring as project elements. There is often extensive regulatory involvement and consultation required to move projects forward.

Projects that do not have listed species are the ones that can derail control efforts. Proponents may be unaware of lesser known regulations such the International Migratory Bird Treaty Act. Project planners may think that, since invasive species control is being done for the purpose of creating or enhancing wildlife habitat, the goal offsets any real or potential impacts or that no regulatory consultation is required. This erroneous assumption has created difficulties for many well intentioned control efforts.

The Santa Clara Valley Water District (SCVWD) identified a project to remove Arundo (*Arundo donax*) from an island in a small lake in Southern San Jose. The control effort was part of a much larger Arundo control program that the agency is conducting county-wide as mitigation for its Stream Maintenance Program. The location of the island is at the confluence of three streams that feed into a large urban waterway (the Guadalupe River). This location and the potential for downstream Arundo infestation made it a good candidate for a control project. Annual high flow events routinely break Arundo loose and carry it downstream where it creates new problems. The island is part of a historical quarrying operation and its soil type makes it prone to erosion as well as unsuitable for most vegetation types.

The island is approximately 0.4 acres and was completely covered with Arundo. The poor soil type and related hydrology created a niche that would support Arundo but was not suitable for most other vegetation types. These conditions created an Arundo monoculture on the island that, over time, had become heavily used by local birds. Casual observation and biological surveys showed heavy use by local birds, including nesting by heron and egret populations. There was a large population of Canada geese using the island for nesting as well. The island is part of a City Park and management of the goose population was ongoing. Any control efforts had to take these realities into account.

Arundo was providing cover, nesting and perching for snowy egrets, black crowned night herons and green herons. The islands location provided protection from predation, as there was no land bridge. Moving mitigation off-site could provide some of the ecological functions found on the island, but the last element could not be created elsewhere. The project required equivalent functions and values to be provided on site with minimal impact to the resident wildlife.

Vegetation Management staff and wildlife biologists developed a strategy that removed Arundo from the island in phases, while simultaneously replanting native species to provide alternative habitat for avian residents. The island was divided into three geographic areas that would be addressed over three to four years, depending on the success of control and the response of the wildlife. The idea was that Arundo would be controlled in one section and then planted with native species, so alternative habitat could develop on site as the non-native vegetation was removed. A revegetation plan including a plant palette was created that addressed the specific issues on the project. This plan was submitted to the California Department of Fish and Game for their review and approval. The larger project has all permits in place but the unique nature of this site required additional consultation with regulatory agencies.

While the strategy addressed the biological issues on the island, it also significantly changed the options for control techniques. The plan precluded the ability to use large-scale control techniques, such as aerial herbicide application or heavy mechanical control. Instead, it required a more surgical approach that consisted of biomass removal and subsequent herbicide application to Arundo re-growth. Biomass removal was done using hand crews as there was no space to station large equipment and there would have been too much disturbance. Crews physically cut the material, loaded it into small boats and transported it to the shore for ultimate disposal off-site. Because the island was completely covered, areas had to be cleared to have room to work and stockpile material.

The implementation plan assessed wildlife functions provided by Arundo and developed a plant palette as well as creative structural elements to meet these needs. Younger plants would not provide adequate structure in the short term so "snags" were installed as alternative structural elements. The soil deficiencies on the island were taken into account in selecting species that had a higher potential for success. Since a major driver was to provide new habitat, faster growing species were dominant choices.

The control plan also looked at the specific avian species using the habitat for nesting and timed control to accommodate nesting cycles. Egrets and herons have longer nesting cycles that extend into the fall that required scheduling the work later in the season. Biological surveys were done each year prior to control activities to minimize impacts.

Arundo control began in 2009. The easternmost third of the island was cleared and Arundo re-growth was treated with herbicide. Aquamaster® was applied using foliar application. A small test plot was done using imazypr (Habitat®) to evaluate herbicide efficacy. Native vegetation was planted and maintained through the first year. Year 2 control took place in late summer 2010 and a second round of planting was done. Re-growth of Arundo in the original control area has been robust and follow-up control has been ongoing. Heavy re-growth was anticipated as the island is essentially one large Arundo rhizome. The proximity of native revegetation to Arundo re-growth has made re-treatment more difficult.

An assessment was done in summer of 2011 to evaluate control efforts and revegetation development. The information was used determine this year's control activities. Though native vegetation is maturing and being used by birds, there is still heavy use of the remaining Arundo by resident birds. This fact is noteworthy because the native and non-native vegetation appears to be used equally with Arundo having a slight edge since it still provides more cover and structure. 2011 control activities consisted of foliar treatment on the remaining Arundo and treatment of re-growth in the Year 1 and Year 2 control areas. The treated biomass will remain for an additional year to allow further development of the native plants. The remaining biomass will be removed in the summer of 2012. The area will then be revegetated and project activities will consist of re-treatment and revegetation maintenance.

The project has been highly successful when one uses the mitigation strategy as the metric for success. Birds are using the new plantings, as well as the remaining Arundo on the island for habitat. The selected plant palette is meeting the needs of the wildlife and developing within acceptable success criteria.

There are a number of negatives of the project that should be acknowledged. Robust re-growth of Arundo requires ongoing effort to suppress. The necessity of having native revegetation alongside Arundo makes chemical control more difficult and forces compromises in both areas. The phased control strategy and concurrent revegetation effort have added more cost and complexity to an already expensive project. Conducting a control project on an island creates an additional layer of difficulty.

Many elements of the project made it an unlikely candidate for control efforts when you factor in all of the modifications required for implementation. At the same time, its location in the watershed offset many of these limiting factors.

This project could have been completely derailed by wildlife issues. Early surveys and the development of a creative control plan that specifically addressed wildlife needs have been critical elements to the project's success. As native wildlife becomes more adapted to a disturbed plant ecosystem, the importance of acknowledging and planning for their presence is essential to creating the best control plans. Better data is needed on how wildlife is using non-native species. Practitioners need to acknowledge the fact that invasive species do provide some habitat value and factor that into the design and implementation of control projects.

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Invasive Spartina Project at a Turning Point: Eradication on the Horizon, Reconciling Clapper Rail Impacts and Charting a Course Towards Tidal Marsh Revegetation with Native Cordgrass

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The baywide infestation of hybrid *Spartina alterniflora* has been reduced from over 800 net acres in 2006 to less than 50 scattered over 35,000 acres of tidal habitat. Only a handful of sites still have greater than 1% cover of hybrid Spartina and prior to major permit delays in 2011, ISP set the goal that 90% of their 170 sites will be to zero-detection by 2013. *Spartina densiflora* was so reduced by annual imazapyr applications that by 2009 the IPM strategy could shift to purely manual removal at 93% of those infestations. Twice-annual inventory and removal of *S. densiflora* by ISP has since depleted the seed bank and sites are approaching eradication.

The biggest challenge to Spartina eradication has been the extensive use of the invaded habitat by endangered California clapper rail. With 85% of the Bay's tidal marshes lost to development, dense stands of hybrid Spartina provided welcome refugia and rail densities soared beyond historical levels at some sites. As predicted, these elevated populations could not be maintained after hybrid removal, especially at areas that were simply mudflat before the invasion created meadows. Fortunately, many high quality marshes were only moderately infested and their clapper rail populations appear to be stabilizing near pre-invasion levels.

Tidal habitat will greatly expand in the coming decades as the South Bay Salt Ponds Restoration progresses and the eradication of hybrid Spartina is a key first step. But years of backcrossing left a large area of the central bay with no native *Spartina foliosa* and successful hybrid treatment has resulted in the absence of a cordgrass component. This presents an opportunity for reintroduction of native cordgrass and other valuable plants like *Grindelia stricta* to both established and newly-opened marshes. ISP began pilot reintroduction of *S. foliosa* in 2010 and is coordinating a multi-year revegetation effort at up to 43 sites where passive recruitment is not expected to be sufficient in the short term.

The goal of the State Coastal Conservancy's Invasive Spartina Project (ISP) at its inception in 2000 was to reverse the spread of non-native cordgrass and eventually eradicate it from the San Francisco Bay estuary through a coordinated, baywide effort. Controlling this noxious weed was the key first step in further tidal marsh restoration including the South Bay Salt Ponds project (SBSP) that will return over 15,000 acres of salt production ponds back to the ecosystem. Every tidal restoration site opened in the Bay over the last 25 years had been quickly invaded and dominated by *Spartina alterniflora* and its hybrids with the native *S. foliosa* and this ecosystem engineer pushed the sites off of a native marsh development trajectory resulting in low biodiversity monocultures that excluded much of the native flora and fauna.

Over decades of backcrossing and introgression, *S. alterniflora* x *foliosa* had formed a hybrid swarm of different morphologies and phenologies that were capable of exploiting all of the tidal niches from mudflats and channel bottoms to the high marsh ecotone. In addition to the loss of native marsh habitat, the invasion threatened the mudflats used by more than one million migratory shorebirds on the Pacific Flyway. Since the hybrids can produce 20 times the pollen of the native cordgrass they can overwhelm *S. foliosa* flowers resulting in hybrid seed production, allowing the hybrid Spartina to spread quickly around the estuary by utilizing all the existing *S. foliosa* as stepping stones.

However, one very important denizen of the Bay's marshes found welcome refuge in the thick, tall stands of hybrid cordgrass, the reclusive California clapper rail (*Rallus longirostris obsoletus*). The loss of 85% of the Bay's marshes to development, along with pressure from introduced predators such as the red fox, resulted in the addition of the California clapper rail to the Federal endangered species list in the 1970s. As the aggressive hybrid cordgrass invasion engulfed more and more of these fragmented marshes, quadrupling in acreage as the ISP was preparing its environmental documentation, clapper rail numbers at some infested Central Bay marshes soared beyond their historical densities.

When Baywide Spartina control efforts began in 2005 after California registration of the aquatic formulation of imazapyr (Habitat®), the hybrid Spartina infestation had expanded to over 800 net acres, affecting approximately 35,000 acres of tidal systems. ISP's task was overwhelming and initially work within clapper rail sites was restricted until after their breeding season ended on September 1. While great progress was made at the Central Bay monocultures that could be treated efficiently by helicopter, this timing scenario pushed all ground and boat-based treatment into narrow windows in September and October when the tides and weather are much less forgiving. In response to these constraints and recognizing the value of invasive Spartina eradication to marsh conservation and restoration, USFWS permitted earlier entry in ISP's Biological Opinion (BO) covering 2008-2010. Sites could now be properly inventoried ahead of treatment to inform the Control Program and a significant number of treatment windows were now available in July and August each year. By the end of the 2010 season, this combination of factors and the expanded use of airboats had reduced the hybrid Spartina footprint to approximately 50 net acres. Although there was still a great deal of work to reach the goal of Baywide eradication, this auspicious progress put that achievement on the horizon as a real possibility.

While the elimination of hybrid Spartina from intact marshes that were lightly to moderately-infested did not have a significant impact on clapper rail numbers, the removal of tall, dense stands of cordgrass where there was previously little habitat value did have the anticipated effect of returning the populations to pre-infestation levels. The invasion of naturally-unvegetated mudflats had established hybrid Spartina meadows that provided ample cover for the rail populations to expand rapidly, but once these monocultures were removed by treatment the components of a native marsh were not present, such as well-defined channels and high-tide refugia from predators.

The decline of rail populations at these sites closely mirrored the reduction in hybrid Spartina cover with a one to two-year lag effect. However by 2011, winter clapper rail call count surveys showed that these declines had leveled out with the population trends stabilizing over the past several years.

At the onset of the ISP, reintroduction of *S. foliosa* to areas of the Bay where it had been extirpated by the hybrid swarm seemed a far-off goal. Planting the native cordgrass in proximity to the hybrid was not practical because it was likely to become an agent for hybrid seed production. In addition, any revegetation at infested sites risked being engulfed by the robust hybrid or being exposed to imazapyr during future treatment. In December 2010, ISP planted two pilot sites with genetically-verified *S. foliosa* transplants to learn more about the best techniques for re-establishment. A vast area of the East Bay from the San Mateo Bridge south to the Dumbarton Bridge needs active revegetation to jumpstart the recovery of these marshes and help them orient to a native trajectory. This region also includes several new marshes recently breached within the Eden Landing complex that are just beginning to vegetate after years in salt production. ISP has developed a Baywide Revegetation Plan that focuses on *S. foliosa* reintroduction, the planting of *Grindelia stricta* at marshes where it is largely absent and the establishment of a high-marsh ecotone at locations where the shallow slope of the adjacent levees will accommodate. Up to 20 sites will be included in the 2011-2013 pilot projects and over the next five years as many as 43 sites will receive a significant planting effort.

As the ISP entered the 2011 Treatment Season, the Coastal Conservancy set ambitious goals that 90% of the sites would reach at least their first year of non-detection of the invader by 2013. *S. densiflora* sites were leading the way because the successful IPM strategy that combined imazapyr application with post-treatment mowing and digging had reduced many of the sites to just a handful of seedlings by spring 2011. However, a major roadblock appeared on the eradication horizon, the delayed USFWS issuance of the Spartina BO. Despite the fact that most of the hybrid Spartina has already been removed and therefore the impacts to rails have largely been realized already, there were still fears within the permitting agency that the previous clapper rail declines could continue. ISP did not receive the BO until September 23 when treatment would have been wrapping up in a normal season; now the largest and most complex sites had to be treated on the poor tide windows of October or November before they senesced. In addition, a number of the largest remaining infestations could not be treated at all and would be allowed to expand and rebound after ten years of work and over $20 million of public funds invested. The Coastal Conservancy is convening a Technical Advisory Committee and a series of stakeholder meetings to address these concerns with the best available science in an effort to help determine the appropriate way forward.

Cost-Sensitive Risk Assessment for Invasive Plants in the United States

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Abstract

Although there is both regulative and legislative precedent for policies restricting introduction of potentially invasive species, lack of a unified theory of invasions – particularly with respect to plants – has impeded efforts to implement screening despite evidence that some observable traits are predictive of the propensity to invade. We develop a cost-sensitive, statistical decision model that assigns species to risk categories according to biological traits. Focusing on invasive plants in the US that are estimated to generate costs of $US 34.7 billion/year, we combine this scheme with estimates of the per species expected economic losses associated with forgoing imports of excluded species and with benchmark values for the economic losses associated with plant pests to parameterize a decision tool for maximizing net economic benefits. Under conservative estimates of losses due to invasion, we estimate that such screening at the national level would generate expected net benefits of $80,000-$140,000 per species assessed.

Introduction

Extensive environmental damage has resulted from the introduction of invasive non-indigenous species, with significant economic costs (Vilà et al. 2010, Colautti et al. 2006, Pimentel et al. 2005, Mack et al. 2000, Parker et al. 1999). Most species introduced into new geographic regions do not become established and most naturalized non-native species do not become pests (Reichard and Hamilton 1997). Of those species that have become invasive, many were intentionally introduced (Mack 2005, Mack et al. 2000, Reichard 1994). While intentional introductions occur across taxonomic groups, we focus here on invasive plants for which the importation of nursery stock has been the major pathway to introduction (Mooney and Hobbs 2000, McNeely 2001, Ruiz and Carlton 2003, APHIS 2007). Indeed, approximately 50% of species now invading wildlands in the continental US and Canada were imported for horticultural purposes (APHIS 2007) and 85% of the woody plant species that have naturalized in North America were introduced primarily via trade in landscape ornamentals, while only 14% were introduced for agriculture or production forestry (Williamson and Fitter 1999, Reichard and Hamilton 1997). Imports of biological materials carries inherent environmental risks since the intent of plant importers is to propagate and spread new introductions and species are accordingly chosen for an environmental match. Given the deliberate nature of most plant introductions, there is therefore both scope and an urgent need to selectively reduce the number of invasive species introduced and spread by human activities.

For this reason, many countries have incorporated restrictions on the importation of biological materials into national environmental policy and several international agreements address the issue specifically. Australia, New Zealand and South Africa, particularly, have implemented stringent biosecurity policies. By contrast, US and EU regulations are less restrictive. In the context of live animal imports, the US relies on a reactive approach based on the Lacey Act of 1900. While other countries like Australia and New Zealand review proposed imports proactively, such policies are currently stalled in the US (e.g. HR 6311 and HR 669) in large part due to concerns regarding the economic burden. However, importation of plants in the US can be restricted under Quarantine 37 (Q37)(1918). Yet, because Q37 regulations were drafted at a time when the risks associated with plant introductions were perceived to be minor relative to their potential economic value, importation of new species for horticultural purposes is presently allowed without formal risk analysis. Instead, the regulatory design of Q37 relies on a list of prohibited plant taxa (currently 95 vascular plant species and five parasitic vascular genera). Taxa not specifically listed as restricted may be imported without a permit (APHIS 2007). To improve vigilance, the Animal and Plant Health Inspection Service (APHIS) has proposed a new regulatory mechanism, NAPPRA ("Not Authorized Pending Pest Risk Analysis"), for screening plants to determine what species should be restricted pending more formal pest risk analysis (74 FR 140, 2009-7-23). Of course, to be environmentally and economically effective, both initial screening and subsequent risk assessment require reliable predictive models.

Methods

In this study, we tested a method for cost-sensitive risk classification of plant species potentially invasive in the United States and Canada. From the US Department of Agriculture Plants National Database (http://plants.usda.gov, maintained by the USDA Natural Resources Conservation Service) we compiled a list of 4,744 non-native vascular plant species that have become naturalized in the United States and Canada as well as 210 vascular plant species identified by Plants National Database as pests within but also native to the lower 48 states. Of the 4,953 species in our "training data set," 1,110 (22.4%) are weeds with 435 of those also designated as noxious by at least one state. The remaining species were categorized as non-weeds.

The first step in our approach was to estimate a predictive model of species' propensity to become either weedy or noxious using readily available data on biotic and ecological traits. Potential predictive variables included a series of biological traits, taxonomy and native range size. We used a boosted regression tree approach to parameterize the predictive model, a common technique for predicting a target variable of interest given several input variables. This combines the basic approach of regression trees – mapping predictors to an ultimate response by multiple binary splits – with a boosting algorithm that adds flexibility and improves fit by removing the restriction of fitting a single tree.

The output of this first step is an estimate of the propensity of a species to become invasive or weedy based on certain attributes. The remaining task is establishing a decision cutoff, i.e., the threshold for acceptable risk. In a second step we identity the optimal risk threshold at which it is no longer rational to accept species for import, conditional on values for the benefits of imports and expected losses should the species become problematic. To characterize trade benefits we estimated the willingness-to-pay for imports from expenditures on plants for planting (P4P) imports to the United States during 2005-2009. Since expected losses from invasion are more uncertain we considered an extended range for this parameter, from a conservative lower bound to an upper bound based on Pimentel (2005).

The fitted decision models were depicted visually in a series of graphical decision boundaries and are therefore easy for decision analysts or regulators to use without special training or expert knowledge. The per species expected net benefit (ENB) of implementing, such a risk assessment model, was calculated over a range of economic parameters. Conceptually, these welfare benefits arise from avoiding losses from invading species, less the forgone trade benefits when a species is excluded.

Results and Discussion

We examine models with both a "full" slate of predictive variables and a more parsimonious "reduced" model using only a few predictors: facultative wetland affinity, seed mass and maximum height. Models were assessed by randomly selecting a subset of the data (75%) for model fitting and then examining performance in classifying the remaining species. This hold-out assessment showed that prediction of weeds (75% accuracy) and state-listed noxious species (76% accuracy) from three traits was sufficiently accurate to be cost effective. In contrast, we were not able to develop stable predictors for the relatively small set of federally noxious species. Our estimates indicate the application of this screening tool would result in ENB per species assessed of $80,000-$140,000 under conservative estimates for the losses from pest plants. Our results demonstrate that cost-effective cost-sensitive screening for invasive plants can be performed using a small set of traits, for which large, publicly accessible databases are available on the Internet, and their interactions.

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Distribution and Impacts of *Arundo donax* from Monterey to Tijuana

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Arundo was mapped in high resolution on all coastal watersheds from Monterey to Tijuana. At Arundo's maximum extent (prior to control efforts) 8,907 acres were present in the study area. Significant progress in controlling the plant has occurred to date with 3,000 acres under treatment in the study area and two larger heavily invaded watersheds with over 90% control completed. Impacts from Arundo invasion were explored in detail and then calculated over the study area using the spatial data set. Included in the study were evaluations of impacts to/from: biomass production, water use, fire, geomorphic and fluvial processes and endangered species. New findings include documentation of a new class of fire event, fires starting in Arundo stands versus wildfires that burn stands (both impacts are accounted for) and significant modification of fluvial processes. The study confirms that Arundo stands on coastal watersheds are extremely productive (high biomass yield) and utilize large amounts of water. All impacts are quantified over the study region and by watershed. A detailed assessment of endangered species impacts for 22 federally listed species is presented, including an Arundo Impact score and level of interaction by watershed for Arundo and listed species populations. Cumulative impact scores are summarized by species and by watershed. A coarse CBA was applied to the spatially defined impacts to determine an approximate monetary valuation of the wide range of impacts. The benefit to cost ratio of 1.9 to 1 demonstrates the value of Arundo control programs, particularly those implemented systematically over watersheds. The spatial data set and Arundo Impact Report are available for download at http://www.cal-ipc.org/ip/research/arundo/index.php

Science, Management and Policy Interactions

Emerging Large Landscape Conservation Initiatives Create New Opportunities to Control Invasive Plants

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Across the country new collaborative efforts are emerging designed to aggregate efforts of private sector conservation organizations, public agencies and the private sector. The defining characteristics of these initiatives is that they not only cross sectors, but they engage multiple jurisdictions, cover landscapes in the many millions of acres, engage the best available science to prioritize land acquisition and management and employ a "protected mosaic" land conservation and restoration strategy rather than solely place-based protection. The emergence of these Large Landscape Conservation Initiatives comes as there is a growing consensus that the most important land and water issues facing North America – climate change, energy development, water management and land use patterns – require something more than business as usual. These challenges can be summarized as follows: 1) the world cannot afford to wait any longer to deal with the threat of climate change and increasingly frequent droughts; yet 2) we are in the throes of historic, worldwide economic dislocations that will make it difficult to mobilize the political will to address that global ecological threat. 3) Meanwhile, security and climate concerns make energy security a pressing priority, just when we must reduce our dependence on domestic carbon fuels. 4) Open lands,including working landscapes, will be called on to provide more "ecosystem services" like clean water, flood protection and secure habitat, while under ever greater development pressure from growing populations in emerging mega-regions. In the Sierra Nevada several large landscape initiatives are seeking to address these issues and the solutions have huge implications for our opportunity to protect native species and manage lands to provide refugia in anticipation of changing climate. The Northern Sierra Partnership is seeking to preserve 250,000 acres of the most important lands within a five-million acre landscape spanning the area from Calaveras County in the south to Lassen County in the north. The Southern Sierra Partnership is engaged in a similar effort to protect more than 300,000 acres of land within a seven million acre landscape spanning the Tehachipi/Sierra Nevada linkage and the southern Sierra foothills.

Science, Policy, and Management Interactions: The Past is Not a Template for the Future of the National Parks

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After its establishment in 1916, the National Park Service (NPS) was strongly influenced by landscape architects, who sought to preserve and enhance the scenery for which many national parks had been designated. Likewise, "good" wildlife such as ungulates were encouraged while "bad" wildlife – predators – were culled. By the 1980s, however, NPS had responded to the science of ecology by "managing for naturalness" as its fundamental paradigm for the conservation of nature. This meant that anthropogenic influences would be identified and rooted out to the extent possible. Non-native plants and animals that were sufficiently extensive to have ecological influence would be removed if the tools were available to do so. Anthropogenically extirpated native species would be reintroduced if possible. Although the ecological concept of homeostasis was already being abandoned by the scientific community, for the national parks it remained an article of faith: Native ecosystem elements and processes should interact unimpeded; the past is a guide to the future. However, increasing use of science to inform policy, and thus management, has led to the realization that there are systemic stressors of such a scale that they are not easily amendable to mitigation. For the national parks of the Sierra Nevada, these include atmospheric contaminants, altered fire regimes, landscape-scale habitat fragmentation, invasive species and climate change. Not long after NPS established an ambitious program to identify and remove introduced plant species as a component of "managing for naturalness," and as its ecological restoration efforts have become far more ambitious, extensive and successful, climate change science is predicting dramatic changes in habitats that will savagely undermine the meaning of "native" and "natural," confounding management goals. Today, NPS is exploring what adapting to climate change may look like for the national parks.

Contributed Posters

Invasive Aquatic Weeds: Implications for Mosquito and Vector Management Activities

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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. The effects of Invasive aquatic weeds are becoming an increasing problem in favoring the breeding of potentially disease-carrying mosquitoes and interfering with vector control efforts. However, there have been a number of collaborative activities among governmental agencies and a variety of natural history and weed management groups and here I present some of the more successful of these activities. I will begin with a brief discussion of how concepts of Integrated Pest management apply to mosquito control and then illustrate specific invasive plants and problems they present.

Integrated Pest Management in Relation to Mosquito Control

Successful control of mosquito larvae and pupae is the primary emphasis of Integrated Pest Management (IPM), greatly reducing the need for aerial spraying. Predators, native species in natural habitats and introduced predators (especially mosquito fish, *Gambusia affinis* Baird and Girard) in artificial ones, are important. Biorational larvicides, such as *Bacillus thuringiensis* ssp. *israelensis* de Barjac (Bti), *Bacillus sphaericus* Neide (Bsp), and maturation inhibitors such as IGR/JHA–Methoprene distributed as granules or briquettes, serve to reduce larval populations, supplementing the effectiveness of predators. Control of invasive aquatic plants improves water quality, discourages mosquito breeding, and enhances predator effectiveness.

Freshwater Invasives

Water hyacinth, *Eichhornia crassipes* (Mart.) Solms, and water evening-primrose, (*Ludwigia* spp.) are among the principal problem plants. These invasives reduce water circulation and inhibit predators. Water evening-primrose infestations can be so dense that pesticide granules and briquettes cannot reach the water.

Saltmarsh Invasives

In estuarine habitats, smooth cordgrass, *Spartina* spp., especially the hybrid *S. densiflora* x *foliosa* (Ayres et al.2007) in 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 & Invasive Spartina Control Project (www.spartina.org)

The SMCMAD is one of the oldest mosquito control agencies in the United States of America, Particularly because of problems with saltmarsh mosquitoes, efforts to form the agency 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 (www.smcmad.org). 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 *S. 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*, *L. Frankenia salina* (Molina) I.M. Johnston, and native cordgrass (Invasive Spartina Control Plans 2008). The herbicide Imazapyr was recently approved for aquatic use in California and has been used along the San Francisco Bay. It is much more effective than glyphosate (Rodeo) on Spartina (Kilbride & Pavegilo 2001). Herbicide spraying activities were timed to avoid nesting clapper rails, Rallus longirostris Boddaert 1783, 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 wildlife habitat, enhanced the aesthetic qualities, facilitated control of mosquitoes with less pesticide use and had good public acceptance (www.smcmad.org/marsh.htm).

Summary and Conclusions

1. Invasive aquatic and riparian weeds are a major threat to waterways, displacing the native vegetation that supports wildlife. They degrade water quality and availability, increase the risk of disease-carrying and nuisance mosquitoes and interfere with mosquito control efforts.
2. Control of invasive aquatic 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.

Acknowledgements

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Mapping, Monitoring and Mowing Medusahead Grass

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Abstract

In an effort to create a strategic eradication plan for medusahead grass, *Taeniatherum caput-medusae*, Acterra conducted extensive mapping and monitoring surveys to assess the medusahead population's current distribution at Pearson-Arastradero Preserve. A team of interns and staff monitored 600 acres using hand-held GPS units and Google Earth to quantify the extent of inva-

sion and delineate a "no-spread line" describing the highest priority populations for removal the subsequent year. Staff decided to use flaming and mowing using scythes, weed whips or commercial mowers as control techniques. In order to remove populations during the "soft-dough" stage, staff monitored growth on north and south facing slopes biweekly after observing the first inflorescence. Staff also conducted frequency monitoring on 20 populations of medusahead to compare the efficacy of mowing and flaming over three years. After removing 344 documented populations, staff continued to monitor mowed areas for regrowth throughout the summer. The careful mapping and monitoring exemplified in this project has enabled staff to efficiently prioritize and plan a comprehensive eradication plan that can be used as an example for land managers in their efforts to remove invasive species.

Introduction

The City of Palo Alto's Pearson-Arastradero Preserve hosts a diversity of native and non-native species within Mediterranean woodland, grassland and scrub ecosystems. Since 1998, Acterra has partnered with the City of Palo Alto and other organizations to restore the preserve and encourage local stewardship. Four years ago, Acterra's botanist documented the spread of medusahead grass, *Taeniatherum caput-medusae,* across approximately 20 acres of grassland. Medusahead is an aggressive, annual grass from the Mediterranean region that outcompetes native species, quickly establishing robust populations that provide poor foraging material for native and domestic grazing animals due to the grass's high silica content (Bureau of Land Management. 2007). Acterra began a comprehensive management plan that highlights effective weed monitoring and a low impact control methodology. The project is currently in its third year and this article focuses on mapping and monitoring methodologies utilizable for other weed management projects.

Methods

Monitoring and mapping for medusahead began in May and June 2010. Land abutting the Preserve and Interstate 280 contained large infestations assumed to be the primary seed source. Starting from initial site infestations, five interns and staff walked through 600 acres of land approximately fifteen feet apart and identified individual to high-density populations. Each population or individual was marked using Garmin GPS units and staff recorded population density and estimated area. Using Google Maps, staff delineated a "no-spread line" to indicate areas with highest priority for removal and intensive monitoring (Figure 1).

Figure 1

Medusahead Populations and "No Spread Line". Green line is "no spread line", red pins are medusahead populations, blue flags are frequency plots, both polygons are commercially mowed sites, and yellow line delineates area of original seed source.

Staff and interns researched various control methods finally deciding on mowing, using weed whips, scythes and commercial mowers and flaming. Mowing results from previous studies indicated high efficacy rates when scheduled during late spring after seeds set but before seed heads matured (the "soft dough" stage)(Hilken and Miller 1994). After observing the first inflorescence, staff monitored twice a week until the majority of populations demonstrated soft dough characteristics.

In order to measure the project's success, staff decided to measure changes using quadrat frequency monitoring that staff found effective especially when targeting one species (University of Idaho 2009). Time restraints reduced the number of random plots monitored using the quadrat frequency method from 25 to 16. Each plot, 10x10 meters, was divided into a one meter square grid by using measuring tapes placed along an allocated x,y axis. Staff tested for medusahead frequency using two test quadrats measuring

25x25 and 50x50 centimeters to determine ideal quadrat size (Table 1). All test sites were mapped and marked with PVC pipes. Four control plots were monitored and the sites were located in close proximity to reduce error.

During early monitoring for the soft dough stage and in conjunction with medusahead removal, staff surveyed most of the preserve for new populations. Additional sites were mapped and subsequently removed. All target sites were marked with PVC pipes and flags to facilitate identification in subsequent years. 344 sites were controlled using scythes, weed whips and hand pulling. Due to unfavorable weather conditions, flaming was feasible for only four sites. City Rangers using a commercial mower removed eight acres of contiguous medusahead infestations with high population density. After all mapped populations were removed, staff continually monitored sites for regrowth and used volunteers to hand pull when necessary.

Results and Discussion

The success of this ongoing project is largely due to thorough mapping and monitoring. Staff discovered over 50 new populations while walking through fields located near previously marked sites. Perhaps high rainfall and late rains in 2011 contributed to the spread of medusahead and offered favorable conditions for late germination. Reducing the distance between staff while surveying fields also increased findings. Staff surveyed areas infested with medusahead multiple times after discovering how easy it was to overlook small populations. 600 acres is difficult to monitor thoroughly; however, it is imperative for controlling further spread and managing infested areas.

Although staff mowed medusahead at the soft dough stage, late rains and varied seed maturation rates contributed to resprouting that continued through mid August. The difference in resprouting rates varied significantly among the different mowing methods. Highest resprout rates occurred after using a commercial mower due to variable plant height, blooming time and the mower's inability to cut sufficiently low. According to visual observations, weed whipping and scything both showed significantly lower resprout rates than mowing. Proximity to drainages, late rainfall and possibly underdeveloped inflorescences contributed to variable rates of regrowth among weed whipped and scythed sites. Both techniques cut grasses very low and mowed patches immediately turned straw colored after mowing, indicating plant mortality. Although population size and density limits the type of control mechanism, the results indicate that weed whipping and scything are the most effective methods for medusahead removal. If areas are too large for weed whipping, be prepared to mow sites at least twice. Also consider that resprouts are shorter and provide additional challenges for commercial mowers. Flaming inflorescences is too cumbersome and ineffective due to fairly impermeable, high-density populations and uncontrollable weather conditions. In subsequent years only weed whipping, commercial mowing and scything, if time permits, will be used as control methods.

Timing and staffing limitations reduced the efficacy of our project with regards to frequency monitoring and removal. Due to staff size, the project had to focus on removal rather than ex-

Control Method	Plot Site #	25cm (%)	50cm (%)	LAT	LNG
BURN	1	50	60	37°23'2.69"N	122°10'43.16"W
	2	30	70	37°23'2.54"N	122°10'44.79"W
	3	30	50	37°23'3.35"N	122°10'44.16"W
	4	50	80	37°23'2.04"N	122°10'44.58"W
	5	30	60	37°23'3.66"N	122°10'43.44"W
	6	40	70	37°23'2.93"N	122°10'43.63"W
MOW	1	40	40	37°23'3.82"N	122°10'44.90"W
	2	40	50	37°23'3.68"N	122°10'45.28"W
	3	60	80	37°23'2.55"N	122°10'46.06"W
	4	60	60	37°23'2.35"N	122°10'42.45"W
	5	50	60	37°23'6.34"N	122°10'44.01"W
	6	40	80	37°23'3.71"N	122°10'46.87"W
	7	50	80	37°23'6.54"N	122°10'43.24"W
	8	90	100	37°23'2.01"N	122°10'44.55"W
	9	80	90	37°23'2.90"N	122°10'45.07"W
	10	20	40	37°23'2.92"N	122°10'43.63"W
CONTROL	1	40	50	37°23'3.94"N	122°10'46.02"W
	2	30	60	37°23'8.08"N	122°10'43.43"W
	3	50	80	37°23'4.45"N	122°10'44.78"W
	4	80	90	37°23'3.14"N	122°10'45.32"W

Table 1

Frequency Monitoring Results

tensive monitoring. Next year, after first inflorescences are observed, staff will begin frequency and soft dough stage monitoring to reduce overlap between removal and frequency monitoring. Staff will also increase controls and number of test plots next year to 25. Staff started removal during early phases of the soft dough stage. For better results, staff will wait until 80% of the population's spathes no longer subtend the inflorescences. This narrows the optimal window for removal so additional staffing will also be necessary.

The next steps include seed drilling native grass seeds into commercially mowed sites and broadcast seeding on weed whipped sites if a population reduction is observed next year. Seed drilling will occur only after population reduction is observed or removal methodologies are changed. Herbicides are not feasible due to the City of Palo Alto's restrictions, so mowing is essentially the only option as the population is too extensive for hand pulling. Staff will continue to monitor intensively along the no spread line and within invaded areas.

An interesting observation by staff noted that the bluebird population increased in 2011. Staff surmised that the 344 mowed sites offered increased foraging ground for bluebirds and aided their population growth. A research project next year will better qualify this observation. In addition, although staff independently developed this medusahead management plan, an analogous project is currently in later stages of eradication and located on Circle Bar Ranch in Mitchell, Oregon. They used similar monitoring and mapping procedures, though instead of mowing, they applied herbicides. The project in Mitchell has observed a significant reduction in population size and appears to be very successful (Oregon State University. 2011).

According to previous studies and staff experience, mowing medusahead is an effective alternative to herbicides and Arastradero's eradication plan will hopefully mirror the success of the Circle Bar Ranch project. Most notable is the careful mapping and monitoring exemplified in this project that enabled staff to efficiently prioritize and plan a comprehensive eradication plan. The planning methodologies described in this report can be used as an example for land managers in their efforts to remove invasive species and improve the sustainability and health of our ecosystems.

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Mechanical Control of Yellow Starthistle: Impacts on Target and Non-target Vegetation

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Abstract

Yellow starthistle (*Centaurea solstitialis L.*) is a non-native pest of rangelands that decreases forage quality and yield. Mowing may control starthistle effectively and complement herbicide use in an integrated pest management strategy, but little research has investigated its effects on non-target vegetation. We monitored biomass and seedbank size of annual and perennial herbs, in addition to starthistle, in response to three years of mowing treatments, either mowing

alone or in combination with solarization tarps or thatch removal. All mowing treatments were very effective at reducing starthistle biomass and seedbank: mowing alone reduced biomass 92 ±2 %, mowing with thatch removal 91 ± 1% and mowing with solarization 95 ± 1%. Compared to seedbank sizes in the control plots, yellow starthistle seedbank decreased by 100% (mowing alone), 92% (mowing + thatch removal) and 100% (mowing with solarization), after three years of treatment. Mowing also significantly improved perennial biomass. Annual species' biomass varied on a year-to-year basis, but was not significantly affected by any treatment. Seedbank sizes of annuals and perennials also did not differ according to mowing treatment. This research indicates that late-season mowing can effectively reduce starthistle biomass without adverse effects on other vegetation and that mowing alone is sufficient to reduce starthistle seedbank size without additional methods of decreasing seed rain.

Introduction

Yellow starthistle (*Centaurea solstitialis*) is a widespread, non-native pest of California rangelands. The plant's seeds are not long-lived in the seedbank and most methods of control focus on preventing or reducing yellow starthistle seedset. Herbicides, prescribed fire and biological control agents have all been shown to be effective against yellow starthistle, but all have drawbacks. The method favored by ranchers is the herbicide clopyralid (Aslan et al. 2009), but clopyralid kills leguminous forage species like clover, can harm non-target native species (Morghan et al. 2003) and, like any pesticide, may induce resistance with repeated use.

Mechanical methods of control (i.e., mowing) may be an important component of an integrated pest management strategy, alternating with herbicide use. Previous studies have shown mowing to be effective only when applied late in the season, when starthistle is in bloom (Benefield et al. 1999). However, little is known about the effects of mowing on non-target vegetation, such as native perennials, or the annual species that make up most cattle forage. And mowing may be more effective if combined with other methods to prevent seeds from being added to the seedbank.

Methods

We identified 24 plots exhibiting 100% yellow starthistle cover in Mediterranean grasslands in the watershed of Ten Mile Creek, near Laytonville, Mendocino County. Plots were randomly assigned to one of the following: mowing alone, mowing in combination with a solarization tarp, mowing in combination with removal of the harvested biomass, or control (no treatment). Because early-season mowing can induce an overcompensatory response, we mowed plots when about 25% of the starthistle was in open bloom and few or no individuals had completed flowering. We used a hand-held, gas-powered hedge trimmer to cut the mainstem at a height of five centimeters aboveground. We never observed regrowth of individual starthistle plants after mowing. In the Mow+Solarize treatment, a four-mil black tarp was pinned down over the mowed biomass for six weeks and removed before the rains began. In the Mow+Remove treatment, all cut starthistle biomass was immediately collected and removed, to prevent seedheads from continuing to ripen and contribute to the seedbank.

Treatments were performed for three consecutive years. To understand the response of the vegetation to late-season mowing, we sampled the following year's spring/summer biomass of annuals, perennials and starthistle, also for three consecutive years. After the conclusion of the treatments, we took soil cores in subplots of the treatment area and germinated seed from the soil seedbank to see what emerged.

Results

Yellow starthistle biomass was affected by treatment method ($F = 21.989$; df 3,71; $P < 0.001$), but not by year of observation. Analysis of pairwise comparisons determined that starthistle biomass decreased significantly in the Mow Only ($t = 6.762$; $P < 0.0001$), Mow/Solarize ($t = 6.922$; $P < 0.0001$), and Mow/Remove ($t = 6.645$; $P < 0.0001$) treatments when compared to the control, but the mowing treatments did not differ from each other. Mowing treatments were effective at decreasing starthistle to zero or near-zero levels; no starthistle plants were observed in any of the Mow Only treatment plots after the second year of treatment and ⅔ of the Mow/Solarize and Mow/Remove treatment plots were also free of starthistle by the third year of treatment. The three-year average yellow starthistle biomass in Control plots was 232.1 ± 54.4 g m^{-2}, but was decreased to 13.9 ± 10.9 g m^{-2} by mowing alone, 17.7 ± 16.9 g m^{-2} by mowing with removal, and 8.8 ± 7.1 g m^{-2} by mowing with solarization.

Biomass of annual grasses and forbs was not significantly affected by treatments, but did vary significantly between years ($F = 8.632$; df 2, 71; $P < 0.001$), with lower annual biomass in 2006 compared to 2007 ($t = 3.811$, $P < 0.001$) and 2008 ($t = 3.339$, $P < 0.01$). The three-year average biomass of annual grasses and forbs in Control plots was 149.4 ± 8.9 g m^{-2}, 201.4 ± 22.5 g m^{-2} with mowing alone, 152.3 ± 14.1 g m^{-2} with mowing and removal and 180.5 ± 18.6 g m^{-2} with solarizing. Treatment, but not year, affected perennial biomass ($F = 4.521$; df 3, 71; $P < 0.01$). Greater biomass in the Mow Only compared to the Control plots ($t = 3.629$, $P < 0.05$) was the only significant treatment difference observed for perennial biomass. The three-year average biomass of perennials in Control plots was 5.6 ± 5.6 g m^{-2}, 33.8 ± 7.0 g m^{-2} with mowing alone, 17.5 ± 7.9 g m^{-2} with mowing and removal, and 25.4 ± 15.6 g m^{-2} with mowing and solarization.

Mowing treatments also significantly affected the yellow starthistle soil seedbank ($H = 17.079$, df 3, $P < 0.001$). After three years of treatment, the reservoir of yellow starthistle seeds in soil was reduced compared to Control in all treatment methods, with 100% reduction (no starthistle seedling emergence) in Mow Only and Mow/Solarize treatments ($Q = 2.746$, $P < 0.05$ for both), and 92% reduction in the Mow/Remove treatment ($Q = 2.234$, $P < 0.05$). Differences among treatment methods in reducing seedbank viability of starthistle were not statistically significant. No significant effects of the treatments were observed on annual or perennial seedbanks.

Discussion and Recommendations

Late-season mowing proved to be very effective at controlling yellow starthistle, reducing the invader to zero or near-zero levels, both in aboveground biomass and the seedbank. Our results confirmed the findings of other studies that have measured substantial reductions in starthistle infestation with late-season mowing (Thomsen et al. 1997, Benefield et al. 1999). However, the "plus treatments" (+solarization and +biomass removal) were not significantly better at reducing starthistle than mowing alone.

For annual species, the principal component of spring forage on grazing lands, biomass and seedbanks were not significantly affected by either starthistle itself or the treatments. Instead, significant differences in annual biomass were observed from year-to-year, suggesting that interannual differences in rainfall drive the pattern. Perennials, most of which were native species in our study sites, seemed to benefit from the mowing treatments. However, the Mow Only treatment was the only one to show statistically significant increases in biomass. Variability was high between years and treatments, perhaps due to the patchiness of clump-forming perennial monocots in this system.

Managers should consider adopting late-season mowing as part of an integrated pest management strategy, especially where repeated herbicide use risks selecting for resistant populations of starthistle, or where prescribed burns are not feasible. Our mowing strategy was more effective than others previously described in the literature, perhaps because we repeated mowing for three consecutive years.

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The Effect of Invasive *Chrysanthemum coronarium* on a Coastal Sage Scrub Arthropod Community in Southern California.

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Abstract

Non-native plant invasions alter basal resources and abiotic factors leading to effects that ripple throughout an ecosystem (Vitousek et al. 1997). Arthropods often mediate these effects – responding quickly to changes and in turn influencing other species (e.g., vertebrate predators; Price 1984). These invasions are of particular concern in the coastal sage scrub ecosystems of Southern California. Habitat loss, encroachment and degradation resulting from dense urban development increase propagule sources and decrease native community resistance. The introduced annual *Chrysanthemum coronarium* is a common invader with largely undocumented community-level effects. Our study tested how the invasion of C. *coronarium* was affecting a coastal sage scrub arthropod community. We performed a field study in the north end of the Tijuana River National Estuarine Research Reserve. Preliminary data from spring 2011 revealed that although total canopy abundance and diversity were not affected by the presence of C. *coronarium*, arthropod community composition changed dramatically. Plots with C. *coronarium* had higher abundances of opportunistic and/or detritivorous arthropods (e.g., dipterans) and lower abundances of herbivores (e.g., hemipterans) than native plant plots. Differences in arthropod communities were associated with the generally greater plant volume, a proxy for biomass and less harsh physical conditions (shadier) afforded by the natives. Individuals of C. *coronarium* were approximately one third of the plant volume of individuals of Artemesia californica and other native plants for the same amount of ground cover. This project reveals that even a proportionally small amount of C. *coronarium* may shift the arthropod community through alteration of abiotic properties and primary producer availability. We recommend that C. *coronarium* be removed at the first sign of invasion or that measures are taken to prevent spread since effects on arthropod community are dramatic and occur quickly.

Introduction

Humans have long moved species beyond their native ranges, both deliberately and accidentally. Non-native invasion of plants are especially troublesome as they can quickly dominate an area and affect the bottom-up processes of an ecosystem, altering basal resources and changing abiotic factors. The arthropod communities of an ecosystem often mediate these detrimental effects, responding quickly to changes and in turn influencing other species, such as vertebrate predators. These invasions are of particular concern in the coastal sage scrub ecosystems of Southern California, where habitat loss, encroachment and degradation resulting from dense urban development increase propagule sources and decrease native community resistance to invasion. The introduced annual *Chrysanthemum coronarium* (common names garland chrysanthemum and crown daisy) is common invader in various regions of the US, including Southern California, where it has formed monocultures (e.g., Cal-IPC 2006; USDA 2011). The effects of C. *coronarium* on arthropod communities and ecosystem processes are largely undocumented. In this study, we tested how the invasion of C. *coronarium* was affecting a coastal sage scrub arthropod community in Southern California.

Methods

We conducted an observational study in the coastal sage scrub community at the Tijuana National Estuarine Reserve in Imperial Beach, CA. Eight to ten plots each of four different plant assemblages were studied: Artemesia californica only, native plant mix, native plant with C. *coro-*

narium mix and *C. coronarium* only. In the spring of 2011, we sampled the arthropod community within the canopy of each plant species within each plot using a gas powered leaf blower adapted to vacuum. We measured physical characteristics of each plant species including plant volume, relative surface temperature and humidity beneath the canopy (relative to ambient) and light attenuation. Canopy arthropod samples were sorted using the morphospecies concept and classified to order. Using Excel, arthropods were partitioned into both morphospecies and order categories for statistical analysis. Species diversity (both number of species per plant and H') and total abundance per plant were calculated.

Differences in the arthropod community within plot types and between plot types tested using nonmetric multidimensional scaling (MDS) on Bray-Curtis similarity indices of log(x+1) transformed data. Significance testing for differences in arthropod composition between plots was completed using analysis of similarity (ANOSIM). Analyses of arthropod community dissimilarities between plots and the particular taxa contributing to the dissimilarity were carried out using SIMPER (Primer Statistical Software, Clarke 1993). The SIMPER results specify what taxa are responsible for the ANOSIM results by comparing the species abundance data between assemblages.

Results and Discussion

Canopy arthropod diversity and abundance

Neither diversity (measured as Shannon's Diversity Index (H') and number of species per plant) nor abundance differed between plots (Diversity: ANOVA, $F_{3,24}=0.37\text{-}1.20$, $p=0.28$; Abundance: ANOVA, $F_{3,24}=0.29$, $p=0.83$). Both diversity (number of species per plant) and abundance increased with larger plant size (Diversity: ANOVA, $F_{1,35}=17.55$, $p=0.0002$; Abundance: ANOVA, $F_{1,35}=46.39$, $p<0.0001$). Native species in this community tend to be perennial and larger than the annual *C. coronarium*. These traits generally make natives more conducive to higher diversity and abundance.

Presence of C. coronarium changes arthropod community composition

Arthropod composition was most different between plots with and without *C. coronarium* (Table 1; Figure 1). Hemipterans, mites, wasps, thrips and spiders were more common in plots with native species and no *C. coronarium* due to more shading and lower temperatures, as well as greater volume offered by the native plants ($R2 = 0.14\text{-}0.37$; $P \leq 0.04$) (Figure 1). Dipterans and one beetle morphospecies were found only in plots with (and mostly on) *C. coronarium*, although drivers are uncertain.

Table 1

Percent dissimilarity of arthropod communities in the four plot types (*Chrysanthumum coronarium* only, *C. coronarium* and native mix, *Artemesia californica* only, and mixed natives). N=8-10 plots per plant assemblage. Data were collected Spring 2011, values are dissimilarity results from SIMPER (similarity percentage analysis).

	C. coronarium only	*C. coronarium*-native mix	*Artemesia californica* only	Native mix
C. coronarium only	52%			
C. coronarium-native mix	60%	65%		
Artemesia californica only	75%	72%	62%	
Native mix	63%	62%	57%	45%

Research significance and conservation implications

The preliminary data of this study shows that *C. coronarium* is having an effect on the arthropod community at the Tijuana National Estuarine Reserve. Although these preliminary data suggest that *C. coronarium* is not having a direct influence on arthropod diversity and abundance, it is having an effect on the composition of this coastal sage scrub arthropod community. This study reiterates the importance of including species composition as indicators of ecosystem resilience, in addition to diversity and total abundance.

Plots with *C. coronarium* had higher abundances of opportunistic and/or detritivorous arthropods (e.g., dipterans) and lower abundances of herbivores (e.g., hemipterans) than native plant plots. The majority of dipterans on *C. coronarium* were from the superfamily Muscidae, which includes house flies and stable flies, known to be nuisances and spread disease by various methods including bacterial contamination of food. Invasion of *C. coronarium* therefore could have not only detrimental effects on the ecosystem but could be a public health concern in the immediate area surrounding the estuary as well.

Differences in arthropod communities were associated with generally greater plant volume, a proxy for biomass and less harsh physical conditions (shadier, more moisture, more constant temperatures) afforded by native plant species such as *A. californica*. Individuals of *C. coronarium* were approximately ⅓ of the plant volume of individuals of *A. californica* and other native plants for the same amount of ground cover. Invasion of *C. coronarium* thus could be lowering overall plant biomass in the ecosystem.

Our data show that even small amounts of *C. coronarium* effect the composition of the arthropod community and thus restoration efforts should focus on early removal (or prevention of spread) of *C. coronarium*, and planting of native species after a disturbance to maintain arthropod community structure. Further study of the effects of *C. coronarium* on this community should include effects on ground-dwelling arthropod species and soil properties to further understand the role of *C. coronarium* in altering the plant and arthropod communities in which it invades.

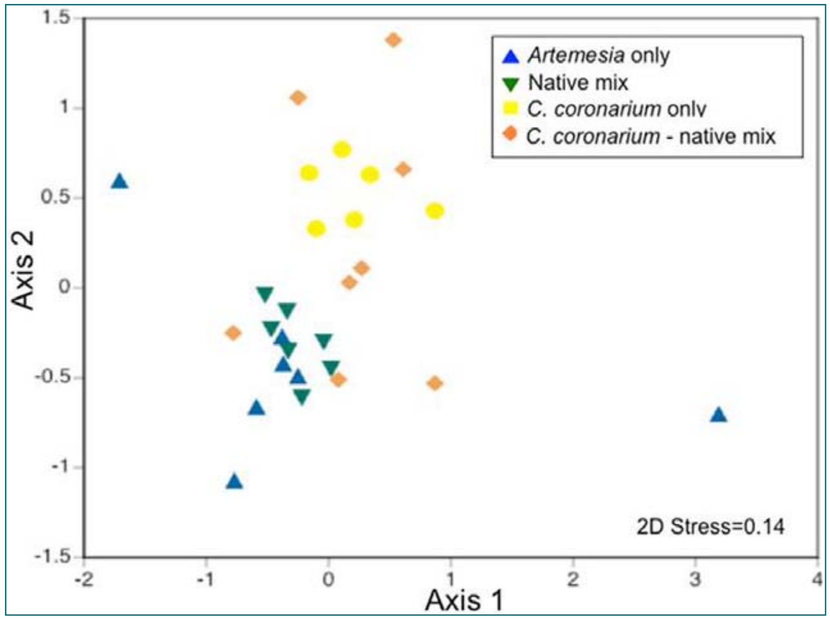

Figure 1

Results of non-metric multidimensional scaling of arthropod communities found in each plot type types (*Chrysanthumum coronarium* only, *C. coronarium* and native mix, *Artemesia californica* only, and mixed natives. ANOSIM, P=0.001; pairwise plots with *C. coronarium* and without *C. coronarium* p≤0.018.

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The Interaction of Soil Surface Gravel Content and Nitrogen Deposition on the Seedbank of the Invasive Grasses *Schismus arabicus* and *Schismus barbatus* in the northwest Sonoran Desert

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The exotic grasses *Schismus arabicus* and *S. barbatus* (*Schismus*) are winter annual invasive species in arid and semi-arid regions that have been shown to increase in cover under nitrogen addition. *Schismus* can produce enough biomass to carry fire in arid regions when subjected to greater than 5 kg/ha/yr of anthropogenic nitrogen deposition during an average rain year. Field studies have shown a decrease in *Schismus* cover in areas that have increasing levels of surface soil gravel. The objectives of this study were to examine the seedbank present in the top five centimeters of soil at eight sites spanning a nitrogen deposition gradient in Joshua Tree National Park. At each site, four five centimeter deep soil samples were taken and composited from the north and south side of four different *Larrea tridentata* shrubs. Two of the shrubs from each site were growing in areas of high surface gravel and two of them in low surface gravel. The soil was then watered continuously under greenhouse conditions and seedlings were identified, counted and removed as they germinated. 39 plant species germinated across all of the plots with an average richness of 6.5 species per plot. Sites located in areas of high N deposition had a higher species richness than those at lower levels. There was no direct correlation between the number of seeds germinated from the seedbank and subsequent field cover of *Schismus* the following year. Principal components analysis revealed that surface gravel content and soil nitrate levels were the most significant factors affecting the seed bank. These results are important because they show that while exotic seeds are present in the soil, physical and environmental factors are preventing them from growing in certain parts of the desert. This may assist managers in predicting areas that are at highest risk of invasion.

Performance Attributes of Aminocyclopyrachlor Herbicide in Controlling Invasive Plants

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Aminocyclopyrachlor is a new class of chemistry known as the Pyrimidine Carboxylic Acids. It is a new generation of herbicides belonging to the family of herbicides known as synthetic auxins. Aminocyclopyrachlor is a low rate herbicide (0.25 oz. to 4.5 oz. ai.), effective on difficult to control species, such as ALS and glyphosate resistant weed biotypes, invasive weeds and brush species. Targeted perennial broadleaf species include leafy spurge, spotted knapweed, diffuse knapweed, yellow star thistle, bindweed, Canada thistle and kudzu. Brush species include huisache, mesquite, poison ivy, oaks, maple, juniper and Russian olive. Annual weeds controlled include kochia and Russian thistle. Cogongrass is labeled for special management control. The half-life of aminocyclopyrachlor ranges from 37 to 103 days. In bareground field soil dissipation studies, the degradation half-life ranged from 80 to 164 days. Aminocyclopyrachlor is metabolized by soil microbes to numerous minor degradation products, mineralized to CO_2 and other unextractable degradates. Leaching is moderated by low use rates and field degradation. Aminocyclopyrachlor is a new DuPont herbicide that received registration in October of 2010 for non-cropland and turf grass uses. Commercialized products of Perspective, Viewpoint, Streamline and Imprelis herbicides were granted federal registrations. Pasture and rangeland registration research continues for control and eradication of problem and invasive annual weeds, perennial weeds and brush species. Technical properties and performance data will be reviewed.

A Predictive Model of *Bromus tectorum* Occurrence in Yosemite National Park

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The exotic grass, *Bromus tectorum*, is expanding throughout Sierra Nevadan ecosystems. *B. tectorum* quickly establishes and dominates in disturbed areas and is known to alter fire regimes by increasing fire intensity and frequency. Therefore, it is of the highest concern for natural resource managers looking to controlling it. The vast distribution of *B. tectorum* is an incredible challenges for land managers working to control its spread. Despite *B. tectorum*'s commonality, it is commonly overlooked and is poorly documented. This lack of data is an unnecessary barrier for Yosemite's land managers trying to understand the species' extent and its potential to spread. In order to overcome our lack of knowledge, a Maximum Entropy (MAXENT) species distribution model for *B. tectorum* was created in Yosemite National Park. *B. tectorum* is documented along an elevational gradient in Yosemite, but only along major roads. MAXENT predicts species distribution using species presence data, biotic factors and abiotic factors. MAXENT models are unique in that they perform well against other habitat models without the inclusion of absence data and therefore circumvent the lack of systematically collected data outside of developed areas. MAXENT predicted that elevation and mean annual minimum temperature are the greatest contributing factors to predicting *B. tectorum* presence. Ground-truthing shows *B. tectorum* has not yet filled its potential niche. This model represents an easy and cost-effective method for Yosemite's resource managers to slow *B. tectorum*'s spread by targeting its distribution and prioritizing areas on the boundary between *B. tectorum*'s realized and unrealized niche.

A Common Data Model for Weed Monitoring Data

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There are many weed data systems successfully serving the purposes for which they were designed. They vary in structure and semantics and in the data management systems used and these differences present stumbling blocks to sharing between organizations, aggregating or moving data between data management systems and reusing the data for new purposes. California's weed managers would benefit from improved weed data support and many of these services require coordination across our existing data systems.

A major goal of this project is to reduce the effort and errors involved in sharing weed monitoring data by defining a conceptual and practical structure into which weed data can be transformed for transport between data capture systems, aggregation systems, online mapping systems and modeling and analysis systems. Those seeking to develop new or enhanced database systems for storing weed mapping data can also benefit by basing their schema or structure on this model, reducing the effort and improving consistency of new database designs. The model serves to structure any weed monitoring data, from simple observations to the time-sequenced data produced by monitoring weed populations and tracking treatments.

Cal-IPC, Calflora, BAEDN and Sonoma Ecology Center are partnering on implementation of the common weed monitoring data model with the goal of exchanging data between efforts and improving support to California weed managers.

Monitoring Environmental Responses to Tamarix Biocontrol and Ecosystem Recovery in the Virgin River Watershed.

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Matthew Brooks, U.S Geological Survey, Western Ecological Research Center and 23 others.

The program to develop biological control of *Tamarix* spp. using the specialist saltcedar leaf beetle, *Diorhabda* spp., has produced some spectacular results and more failures, but also some exceptional political conflicts, primarily over perceived threats to endangered southwestern willow flycatchers (SWFL) nesting in tamarisk. This controversy was elevated by the recent introduction of Diorhabda into the Virgin River in Utah, Arizona and Nevada, the only location where the beetle has established within the Critical Habitat of the SWFL, and has led to lawsuits and massive breakdown of the biocontrol program. In this context a multi-disciplinary research team has implemented a large-scale ecosystem and biodiversity monitoring program to document responses of biota and ecosystem functions to the introduction of this novel herbivore into the riparian system. This will allow us to track both short-term effects of tamarisk defoliation, as well as long-term responses to the changes in the structure of the vegetative assemblage. These data will provide the objective information needed to eventually resolve the legal dispute concerning the biocontrol program and illustrate the process of anticipated ecosystem recovery, particularly in light of proposed restoration of native riparian vegetation in key locations.

Mapping Invasive Weeds: Scaling Up and Down for Different End User Scenarios

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The San Francisco Estuary Invasive Spartina Project has been mapping invasive Spartina using GIS and GPS since 2001 in support of control efforts and to analyze the efficacy of control efforts. We have reduced the Baywide population to approximately 10% of its former cover, but now our site-level maps tend to make the situation look worse than ever before! This is a result of the point/line/polygon conundrum: in a GIS, by default, points are usually displayed much larger-than-life as one zooms out, whereas lines and polygons maintain their true on-the-ground size. In the past, we often mapped large, uncontrolled meadows of invasive Spartina as polygons and lines. Following six years of successful regional treatment, we now map more point features to record the many small, remaining patches requiring treatment. When zoomed out to the site level, this extensive point data gives the impression that populations have increased dramatically compared to the previous polygon data. To resolve this false impression, we have begun using a dot density symbology in ArcMap to allow for a more realistic display of the actual footprint of invasive Spartina remaining at the site level. We will explain the process we went through to develop the old and new layers and give examples of how we now use both to ensure that our maps display our data at the appropriate scale for different end user scenarios.

Public-Private Cooperation Results in Improved Restoration of Reed Canarygrass (*Phalaris arundinacea*) Infested Areas

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Montane meadows are among the most rare and biologically diverse vegetation types in Sequoia and Kings Canyon National Park (SEKI). Reed canarygrass is a major threat to native wet meadow and riparian plant communities throughout developed areas within the Grant Grove area of SEKI. Many of these meadows are located with Wilsonia, a private in-holding in SEKI, and upstream of National Park Service (NPS) properties. Effective eradication of reed canarygrass on NPS properties required control of populations on private property. Prior to project initiation, residents of Wilsonia were contacted to determine interest in allowing control and restoration efforts on private property by NPS personnel. Many residents signed cooperative agreements to allow work to be conducted on private holdings. Eradication measures were conducted in FY 09 - FY 11 and have resulted in successful control of reed canarygrass. The focus of work in FY11 was to plant native species in areas where reed canarygrass has been successfully controlled and restore functioning wet meadow ecosystems. Residents have taken a strong interest in the project and several have volunteered time with NPS crews. The success of the project could not have been achieved without participation from Wilsonia residents and shows how important cooperation between public and private entities is when attempting to restore functioning ecosystems.

Tulare County WMA Yellow Starthistle Control Program

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Yellow starthistle colonizes an estimated 20,000 acres of Tulare County foothill range. UC Cooperative Extension Tulare County (UCCE) office conducted trials from 1997-2008 to determine effective control strategies for yellow starthistle. In 2000, the Tulare County Weed Management Area (TCWMA) was established by UCCE Tulare County; USDA Natural Resources Conservation Service and Tulare County Agricultural Commissioner, as lead agencies, and United States Forest Service, US Geological Survey, Sequoia Riverlands Trust, Tulare County Cattlemen's Association and California Native Plant Council as cooperators. Establishment of the TCWMA facilitated the acquisition of a California Department of Food and Agriculture (CDFA) grant in 2001 that provided funds for a yellow starthistle control program. Success of this program led to initiation of a cost-share spray program in 2002. Between 2002 and 2011 a total of 2,228 acres of infestations have been controlled through several years of Transline and Milestone applications. In 2011, the cost-share program experienced the highest level of participants since being enacted. The cost-share program has significantly reduced infestations within rangelands and provides landowners an affordable method of control. Landowners are subject to a cost-share of $50 up to three acres and $15 per acre for any area greater than three acres. In 2009, CDFA and ARRA funds were appropriated to continue cost-share program, hire a program coordinator and develop a "Leading Edge" program effort. Acquisition of a program coordinator has improved the program's impact through various community outreach efforts, improved surveying and monitoring strategies and improved use of GIS. Currently base line state funding for the yellow starthistle program is at risk; however, additional funding sources are being sought. Continuation of this program is important to the communities and would have a positive impact on the conservation of biodiversity within Tulare County and surrounding natural lands of the National Parks and Forest.

The Evolution of Arundo Removal Efforts on Camp Pendleton

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In February of 2010, Camp Pendleton completed initial removal efforts on the final 200 acres of arundo (*Arundo donax*) and salt cedar (*Tamarix* spp.) infestations on the Santa Margarita River. Since treatments began in 1995, the methods used to remove arundo have been changed or modified over the years to account for a range of issues facing the Base. From pulling arundo rhizomes out with a backhoe to mowing and leaving the biomass on site, methods have been altered to achieve better results with less money. The presence of threatened and endangered species have necessitated treatment methods and timing to change over the years to minimize negative impacts to riparian and estuarine wildlife. Eventually native plantings were incorporated for the final segment to shorten recovery time and discourage exotic annuals from dominating the site. Other issues, like the floods of 2010, caused unintentional effects that required additional efforts outside of the treatment area.

With the help of numerous individuals, organizations and companies throughout southern California, Camp Pendleton has removed more than 700 acres of arundo and 140 acres of salt cedar from the Santa Margarita River and other drainages.

Eradicating Algerian Sea Lavender (*Limonium ramosissimum*) from San Francisco Bay Wetlands

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Beginning in 2006, several densely growing populations of Algerian sea lavender (*Limonium ramosissimum*), were discovered in San Francisco Bay salt marshes. A perennial, salt-tolerant forb of Mediterranean origin, Algerian sea lavender has spread to marshes and tidal lagoons in southern California, from San Diego to Santa Barbara. There, the plant displays invasive characteristics including broad salinity tolerance, prolific seed production and the ability to compete with native plants.

In San Francisco Bay, Algerian sea lavender has been found in the high marsh and upland transition zone where it forms near-monocultures and competes directly with native salt marsh species. At the upper end of this elevation range, Algerian sea lavender grows taller, more robustly and produces more seed, competing directly with perennial pickleweed and altering high tide wildlife refugia habitat.

San Francisco Bay Algerian sea lavender infestations have been detected on scattered marshes and cover approximately four net acres within a combined 50 acre gross area. Such limited establishment offers a rare opportunity for eradication without great economic expenditure and without the harm caused by allowing this invasive to spread. Eradication also pre-empts the long term impacts and loss that will be required to control this species if it is not stopped in the early stage.

Many partners around San Francisco Bay have already initiated detection and eradication efforts against Algerian sea lavender and are actively coordinating with the Bay Area Early Detection Network (BAEDN) on this and other priority eradication species. BAEDN is working to bring additional stakeholders and support on-board. Working together we can eradicate invasive Algerian sea lavender from San Francisco Bay. Please report new sightings to the appropriate land managers as well as the occurrence database at www.Calflora.org.

Population Expansion and Regional Management of Red Sesbania (*Sesbania punicea*) in California

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Red sesbania is an invasive South American shrub forming dense stands along California waterways. It can increase flooding, alter hydraulic roughness in shallow channels and decrease biodiversity of riparian corridors. Over the past decade, red sesbania has rapidly expanded its range in California, emphasizing the need to prioritize eradication sites at a regional scale. To accomplish this, we updated baseline location data in summer 2010 using field surveys. The regional survey identified major propagule inputs, upstream and downstream extents for each watershed and provided data in areas where there was no previous information, such as the Sacramento River between Redding and Verona. We then employed the Weed Heuristics: Invasive Population Prioritization for Eradication Tool (WHIPPET) to prioritize individual populations for eradication. WHIPPET prioritized small populations isolated from the main infestation, as well as outliers in residential areas. WHIPPET also identified small, upstream populations along riparian corridors that act as sources for seed migration downstream as management priorities. Results from WHIPPET and expert opinion were then used to select a location for a control program. Churn Creek in Redding was selected due to its upstream location, size of infestation and engagement of community groups. Western Shasta Resource Conservation District was engaged to remove red sesbania biomass from Churn Creek and volunteer watershed groups were trained to monitor the creek in the future to look for re-sprouting sesbania plants. This type of community partnership is vital in maintaining long-term control of this highly-invasive plant.

Evaluating the Effects of Horizontal and Vertical Mulches for Restoration of a Degraded Site in the Mojave Desert: First Year Findings

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Anthropogenic disturbance and the invasion of exotic plant species are major drivers of ecosystem change in California's deserts. These two phenomena can lead to soil compaction, loss of species diversity and alteration of ecosystem processes, such as hydrology and fire regime. Restoration in arid environments poses a difficult challenge for conservationists and managers due to the harsh, dry climate and slow recovery of native plants. In this study, we compared two mulching strategies used to encourage recovery of annual plants at a heavily disturbed, highly invaded site in the Mojave Desert. Horizontal (H) and vertical (V) mulches were constructed in shrub interspaces to simulate a "fertile island" effect. These treatments may create a favorable environment for the germination of native annual plants and attract rodents, aiding in soil decompaction. Vegetative percent cover, biomass and species richness were measured in both mulch treatments, as well as open areas (OA) between shrubs and beneath *Larrea tridentata* (LT) shrubs. Rodent burrows were also counted. Invasive species made up the majority of the plant cover in all treatments; however, functional group abundance differed between treatments. V plots had higher cover of invasive forbs than both H and OA plots. Native annual percent cover was twice as high in LT and OA plots as H plots. V plots had intermediate cover but had higher native species richness than LT plots. Total productivity analyses indicate that V plots are more productive than H and OA plots but only one-third as productive as LT plots. Mulch did not increase rodent activity in the first year. This study will be monitored in future years and the information collected can be used to make management recommendations for other desert sites.

Results from Four Years of Early Detection Invasive Plant Monitoring in Golden Gate National Recreation Area.

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Since 2007, the San Francisco Area Network, Inventory and Monitoring Program have collected data on invasive plant species occurrences in Golden Gate National Recreation Area through its Invasive Species Early Detection Program. This monitoring effort is primarily focused on non-native plants that are not yet well-known for their ecological and/or economic impact to the study area, but have a high potential of being problematic if left unchecked. Early detection surveys occur along roads and trails only. The roads and trails are sub-divided by the subwatersheds they cross, thath are ranked as high, moderate and low priority. Portions of a road or trail that occur within the differently ranked subwatersheds have a corresponding sample frequency of every year, every two years and every five years, respectively. Thus far, monitoring efforts have resulted in over 2000 new occurrences of targeted invasive plant species. Overall, the number of new occurrences each year has decreased while the number of treatments (by hand-removal) has increased. Separate analyses of detection rates for each species reveals that for some, we have likely found most of the extant populations and they do not appear to be colonizing new areas rapidly. However, the rates of new occurrences for other species are either steady or climbing. Separate analyses of the spatial distribution of early detection occurrences also confirms that subwatersheds in close proximity to human disturbances or urban settings have higher invasive species richness and a higher number of invasive plant occurrences than areas in more natural settings. Continuation of these surveys and their linkage into the Bay Area Early Detection Network will improve our understanding of invasive species patterns and will be used to maximize the effectiveness of control efforts within the park and region-wide.

Comparison of Four Herbicide Treatments on *Oxalis pes-caprae*

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Oxalis pes-caprae has increasingly become a management issue for managers of California coastal systems. To better understand the effects of herbicide on *Oxalis pes-caprae*, a trial was conducted in 2009 in the Presidio of San Francisco. Four herbicide treatments with five replications were applied to 1 x 1 m plots in December 2009. The treatments were: A. 1% Garlon 4 Ultra + Competitor; B. ½% Garlon4 Ultra + Competitor; C. 1% RoundUp Pro Max + Trifol water conditioner; D. 1% Rodeo Aquamaster +Syltac + Trifol water conditioner. Oxalis individuals were counted in an inner 0.5 x 0.5m area in October 2009 and again in December 2010. A one-way Anova revealed a significant difference between the change in mean number of Oxalis individuals pre and post treatment ($p<0.05$). Only Treatment B was significantly different that Treatments A,C and D in 2010 ($p = 0.03$). Comparison of results to a study of manual treatments on *O. pes-caprae* (Stringer 2005) suggest that herbicide may be a more effective method than the manual treatments conducted in that study, with the exception of tarping.

Evaluation of Control Techniques for Velvetgrass (*Holcus lanatus*) in the Kern Canyon of Sequoia National Park

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The Kern Canyon is the least developed and most naturally-functioning watershed in Sequoia and Kings Canyon National Parks and visitors to the Kern experience among the most intact wilderness character in this region. Velvetgrass (*Holcus lanatus*) is one of only nine non-native plant species known in the Kern Canyon and is present in relatively few patches. Velvetgrass was detected very recently, in 2004 and 2006, and is extremely invasive in montane meadows, forming pure stands that displace native meadow vegetation. It has recently become very widespread in wilderness meadows in Yosemite, where they've begun large-scale control efforts. In 2009, we initiated a control project to investigate the efficacy of the control methods for eradication of velvetgrass: hand-pulling with large work crews (> 10 people), glyphosate herbicide application and tarping. Velvetgrass percent cover and stem counts have been recorded annually for the hand-pulled and herbicide treatments. The tarping treatments remain in place for three growing seasons and vegetation measurements will be recorded following removal to allow comparison to the other treatments. After the initial two years of the study, hand-pulling and herbicide application have resulted in greater than 50% reduction in velvetgrass cover. Preliminary observation of tarped areas shows near elimination of vegetation after two growing seasons. The results from our comparisons will provide managers with useful information for managing velvetgrass infestations.

Progress in the Restoration of the Habitat of Fountain Thistle (*Cirsium fontinale*) Invaded by Jubatagrass (*Cortaderia jubata*)

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Fountain thistle (*Cirsium fontinale*) is a rare native thistle endemic to the San Francisco Peninsula that is listed as a federal and state endangered species. Two of the populations have been heavily invaded by jubatagrass, which displaced fountain thistle from much of the habitat.

One population occurring on Caltrans property was reduced to fewer than 100 plants after invasion by jubatagrass. Through the efforts of Jacob Sigg, volunteers of the California Native Plant Society and Caltrans, all of the jubatagrass has been removed and the population is recovering to a level of several thousand plants. In a study of the efficacy of establishing the native bunchgrass California hairgrass (*Deschampsia cespitosa*) to restore fountain thistle habitat and prevent re-invasion of non-native plants, 1,000 hairgrass plugs were planted in 2009 and were individually marked with metals tags. Based upon the retrieval of metal tags from plants failing to grow, it is estimated that approximately 50 per cent of the plants have become established.

Another fountain thistle population invaded by jubatagrass occurs in the watershed of the San Francisco Public Utilities Commission (SFPUC) and almost all of the jubatagrass has been removed by SFPUC staff and Earth Stewards of the non-profit group The Garden Project. An annual monitoring study of the population employing permanent transects has been conducted to track the progress of re-colonization of the invaded habitat. The study revealed that the population expanded by an average distance along its outer edge of 13.2 feet between 2007 and 2011 or an average of 3.3 feet per year.

The rapidity of re-colonization seems to indicate the presence of some unknown mode of long-distance dispersal of seeds, or of unexpectedly long seedbank dormancy, or both. Secondary invasion by invasive plants remains a serious problem impeding reclamation of fountain thistle habitat at both sites.

Developing, Evaluating and Prioritizing Alternatives for Noxious Weed Management Using a Weed Matrix

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The Bureau of Land Management's (BLM) Carson City District Office is responsible for managing 5.5 million acres in western Nevada and eastern California. The agency hires seasonal employees each year to assist with noxious weed abatement projects. Managing for noxious weeds is complex and can at times seem overwhelming, especially to those who are new to the field and new to the area. In order to help new hires acquaint themselves with the BLM's noxious weed management goals and speed up the orientation process, the Bureau created a Weed Matrix, drawing upon principles known from multi-criteria decision analysis. The Weed Matrix was designed to develop, evaluate and prioritize management alternatives based upon site specific biological, temporal and environmental information.

In 2010 the BLM contracted with the Chicago Botanic Garden to hire nine interns to assist the BLM in noxious weed management. The interns were from different parts of the country and were new to western Nevada and eastern California. Their initial task was to develop a Weed Matrix for several weed infested areas. The interns compiled data on weed biology as a way to "know your enemy" and then compiled information on integrated pest management tools that were available to them. With this information the interns were able to categorize weed infested areas based upon realistic management goals of eradication or containment over time. The interns then prioritized treatment areas and utilized mechanical and chemical treatments as a first step in managing these areas. In addition the interns hand seeded native species as a means to provide competition against weeds and also collected seed from native plants for future restoration.

The Weed Matrix developed by the 2010 team was useful to the 2011 intern team as it documented the progress made in 2010 allowing the 2011 team to pick up where the previous team left off.

With the management alternatives derived from the Weed Matrix, seasonal employees were better able to define realistic goals and objectives that had the greatest potential for success given the time and resources available to them.

Discussion Groups

Prioritization schemes for weed management

Co-leaders: John Knapp and Gina Darin

"Your worst weed is not my worst weed." We all think that our weeds are more important than everyone else's weeds. Potential funding agencies have to choose which projects to fund, and therefore they have to prioritize. Weed workers should, too.

Have you attempted to prioritize and, if so, how? Coming up with the right questions about how to make a judgment is difficult, as is identifying the criteria for prioritization. A challenge is to separate personal bias from reality on the ground.

Prioritization examples from the discussion group:

By species and populations, but there are data gaps, with missing plant populations.

By linking snapshots in time to the current situation via comprehensive data

By risk to natural features

By feasibility

By available methods of control

By available funding

By landowner access

By geography—keeping clean areas weed free vs. treating highly infested sites

CDFA attempted eradication on A rated weed sites, but they were only successful with smaller infestations. Keep in mind:

- The reason to prioritize is to promote success
- Define what you want to do: eradicate or control. Identify your goals
- You will need several tiers of prioritizing.

Prioritizing is part of a process:

- Inventory weeds
- Survey sites
- Prioritize control
- Make a management plan
- Treat weeds
- Monitor
- Analysis
- Re-prioritize

You must define your goals and objectives.

Even before you inventory, you have to prioritize what to inventory.

Fighting a weed if you don't have a good inventory/survey is likely a waste of money.

Projects are often funding-dependent, so you need good data on the plants that you have funding for.

We have to remember that the end goal is to get rid of the seed bank. Treating a 50-year seed bank with three years of funding is not ideal. You have to plan. Keep your eyes on the ball.

Mapping is key, but it takes time. Map as you treat, and update your maps so you can update your management plans.

Cal-IPC now has regional maps for species that may be coming your way.

National and Global Efforts:

Pre-screening for weeds

- Biosecurity Australia: The Australians are very careful about allowing new plants into the country. They say: Plants are guilty until proven innocent.
- USDA Q37: AKA Plants for Planting. The USDA is checking both the soil that comes into the country for pathogens AND the plants themselves – finally. They put the plants through a risk assessment procedure.

Post-Border work

- Use the Cal-IPC inventory to figure out how to work with your weeds. It may not apply to your part of the state, so look online at the regional maps for trends in your area.
- Use the CDFA plant pest rating list for guidance.
- Alien Plant Ranking System
- Natureserve Invasive Plant Assessment Protocol

John's Prioritization Method (done for master's thesis in 2002)

This work was done for the Catalina Island Conservancy. What were the data gaps? John did 466 transects=600 miles=6 months of work. 72 different weeds were found. John raised a million dollars with this information, which he used to create a big map. This information gave him a good idea of the feasibility of control and of management of the weeds.

Do landscape level surveys:

- Number of populations per species
- Median population size per species
- Net area infested per species
- Consider seed viability too (if you know what it is)

WHIPPET (Weed Heuristics: Invasive Population Prioritization for Eradication Tool) is designed to help prioritize weed infestations for eradication based on potential impact, potential spread, and feasibility of control.

Use WHIPPET if:

- You have access to Microsoft Excel and ArcGIS software
- You can map or have mapped all occurrences of highest priority weed species in and around your region of interest and
- You're considering eradication targets and have a control method that can keep every plant in a targeted population from flowering every year until you have exhausted the seed bank.

Using WHIPPET: (see Gina's handout for more details)

- Identify your weeds
- Inventory: ID priority weed species and inventory occurrences:
  - Gross size of infestation (survey area)
  - Net size of infestation (treatment area)
  - Accessibility of site
  - Detectability of infestation before seeding
- Gather background info on each species and assign a score. Sometimes you will come up with surprises.
- Run the program. It will do the ranking for you. You can swap layers out for your own special situations. For example, if you are working in a park, then you would not use the "distance to parks" attributes. And you always need to do a reality check on the ground. Data out is only as good as the data in.
  - Calculate priority and review output. Consider external circumstances.
  - Use the Weedsearch tool to estimate project cost and the probability of success
  - Apply the prioritization

Tips:

- If you fail to plan, you are planning to fail
- Start doing these information-gathering steps for better success in getting funding
- You will be more successful and get more done in this competitive time for grants
- You need GIS software
- You can use WHIPPET on any spatial area, but not too many populations at once – best for eradication targets.
- We will be able to get WHIPPET online in the future.
- Get information from Gina now, gsdarin@water.ca.gov.

Licensing and Contracting Mechanisms for Getting Work Done

Leader: Mark Heath, Shelterbelt Builders

Summary

A primer on hiring or being a contractor for invasive species management. Learn what licenses, certifications and qualifications are necessary and/or recommended to do weed work in California. Do you know what types of contracts control fixed costs versus allow for flexibility and uncertainty? Within those contracts, how can you insure quality treatments and get results without spending too much? How can you make sure your contractors are working safely? Learn about how different types of funding impact your overall budget, Department of Labor reporting requirements and the need for registered apprentices on your projects. Do you know the

difference between the Davis-Bacon and Service Contract acts? If not, come and join us and bring all your other questions for an engaging discussion on the business side of weed management!

The topics people were interested in:

- Hire contractors, project managers
- Want to be contractor, volunteer, property manager

Taking care of weeds

Host of issues: project done a lot of gray area
14 years: private contractor

Different funding sources for work

- State level, cities, counties
- Federal - More discretion needed

Private land, NGO land – Which type of licensing do you need?

CA licensed contractor – State board is the Department of Consumer Affairs

(A), (B), landscape contractor → General engineer contractor →Public works →covers fixed works→ dams, road, constructing harbors, irrigation, drainages, flood control, parks, mines, land leveling

(B)→General contracting →built, being built, to be built

(C) →Specialty trade →Landscape→C27 → functionally improve, plot of land

(D)→More specific →tree trimming, tile grouting

LTO: Licensed Timber Operator

- Everything
- Limited → commercial cutting and removal of minor products

Farm labor contractor →regulatory board →industrial relation

dir.ca.gov/

CDPR → within the EPA→pest control business → safe and legal application of pest control

Four main licenses

- Labor Law & Public funding →depending on which side you pay your employees!!!
- All public works → prevailing wages → money to pay union labor NOT LIVING WAGES, MINIMUM WAGES
- Maintenance Law → umbrella law for public works
- Money comes from state or federal money →pathway for funding a project →whichever one is hired, wages are paid → writing up a contract → capital phases

  Federal contract falls under contract act

  SCA → routine work
- Prevailing wages vs. living wages
- Landscape Maintenance → CA state → minimum wage

  Landscape labor improvement → $36 with a 15 min increment of work

  Sometimes off the job site doesn't count
- Moving around→ prevailing wage→ licensing board

Recognized craft codes

Choosing the site

Public agency will define what the work is!!

The contractor liable to pay all the wages to the employees

Broad spetrum of licensing job

Agencies define clearly for fair competition

Federal < 5 million dollars small business

Low bid project→ sometimes ranking by experience and questions

Super solid documentation for disqualifying any contractor, sometimes references dangerous thing

Work with NGO's sometimes having less restrictive MOU's, and contracting system

Scoring } Matrix→ USFS
Lowest qualified bid and
Contracting side based on experience and references

Working side

With specifications and design →lowest bidder is ok → else qualified contractor good choice

Pursue certification → important license or certificate → contractors' license C27 → broader spectrum

Aquatic/Riparian Weeds: State-Level Rapid Response Issues

Submitted by Lars Anderson, Facilitator

Background and Summary:

New infestations of aquatic and riparian weeds in California should be met with expeditious, "Rapid Response" actions. These actions include verification of the species, delineation of the infestation and immediate containment and control.

However, due to a multiplicity of state and federal agencies with different authorities to act, differing aquatic site and water-use responsibilities, and highly variable resources, effective rapid response actions often delayed from weeks to months, or longer. This situation is further complicated because some agencies such as California Department of Boating and Waterways (BWW) have legislative authority for control of only two non-native aquatic weeds: Brazilian waterweed (*Egeria densa*) and water hyacinth (*Eichhornia crassipes*). Thus, when a new invasive aquatic weed, South American spongeplant, was found in the Delta in 2007, BWW had no authority or mandate to use its resources in a "rapid response" mode. Even though its crews were able to detect and physically remove some of the plants, they could not apply effective foliar-type herbicides that are already part of their water hyacinth control program (WHCP). Historically, the California Department of Food and Agriculture (CDFA) would have responded to such as invasion, and indeed, CDFA took initial steps to eradicate this plant from a small site in northern California, and removed some plants in the San Joaquin River in 2007-2008. However, CDFA staff, programs and resources in general have been reduced in the past year, and further reductions are likely.

Two overarching issues also tend to interfere with rapid response and even general aquatic plant management: Compliance with NPDES, and the Endangered Species Act (ESA). The discussion focused on these and several other issues that are outlined below.

Lastly, participants identified several potential options for developing sustained resources to mount effective prevention, early detection, and rapid response capacity.

Topic 1: Identification of Impediments and related issues to Rapid Response in California

ISSUES:

- Water Usage (storage) and impacts: How do we better identify costs and other impacts of aquatic weeds on overall water use and storage?
- Managing ballast water (new infestations): What is CA doing re ship movements (e.g. along the west coast – not just trans-Pacific)?
- Who and where to Call or Contact when some unusual aquatic plant is found? At the local level, Tahoe Basin is pretty well coordinated; CDFG Web site is fairly good for reporting. There is a need for more uniform approach by agencies to do the following:

  Coordinate materials for outreach and Education

  Example models are Minnesota and Oregon: both have great existing state-wide program

  Involve Public ("Citizen Science); more useful smart phones apps

- Mosquito and invasive aquatic weeds connections:

  Displace native flora, not just mosquito control problem.

  Cited Carl Bell project on *Ludwigia* sp. → successful

  Opportunity for collaboration with mosquito abatement programs

  Cited example in Colorado and purple loosestrife management

- Aquaculture: Both freshwater and marine (mariculture) areas have been neglected (e.g. algae control and off-flavor; interference with harvest, oyster production).
- Landscape Level management: Too many state (and federal) projects focus on just the current "high priority" weed – not a multispecies (i.e. multitarget) approach. This results in cascade and replacement effects whereby successful management of on target simply open the niche for another.

- ESA (Endangered Species Act): Several months to year-long delays in being able to take rapid action. There needs to be a streamlined process and some "generic" programmatic approvals so that rapid responses can be implemented when listed species are present.
- NPDES: Need to resolve both state (CA) and interstate issues so that rapid responses can be implemented with minimum delay in compliance with NPDES. For example, when is it an emergency situation?
  - Knowing ID, management techniques, roles and responsibilities
  - Knowing authorities: These are essential to compliance with both ESA and NPDES
- Advocacy and NGO's: Need to connect and network with NGO's so that there is a common message to the public and to funders (State legislative bodies).

Topic 2. What actions are likely to resolve these issues?

SOLUTIONS

1. Resource limitations

- Increase State Boat Registration Fee. There are approximately 800,000 boats registered in California. If the average annual cost of registration were raised by just $5 (< 14 cents/day!), this would generate $40 million per year. If 20 % of this $40 million ($8 million) could be kept in a cumulative, revolving, rapid response fund, then effective responses to new or recently introduced AIS could be handled effectively assuming adequate coordination among state agencies.
- Aquaculture/mariculture: User fees for aquaculture businesses: Since aquaculturists are both potential pathways of AIS and benefit from the absence of AIS, a fee is a reasonable approach – just as a "gas tax" is paid by all users of the roadways.
- Aquarium-related retail fee: Since "hobbyists" aquarium owners and related suppliers are a known pathway for AIS, a small user fee could be attached to purchases of tanks, animals, plants and other paraphernalia related to this hobby. Even a 1% fee would generate millions of dollars.
- Aquatic Plant Nursery User fee: Same rationale as for aquaculture business and aquarium trade. Note: Some program are in place the aim to reduce "releases" of non-native AIS:

Note:

Habitattitude: There is currently a national public awarness program aimed at reducing "releases" of AIS into the environment (i.e. not releasing fish and aquatic plants into the wild) www.habitattitude.net

However, this program doesn't generate revenue for use in EDRR, nor does it actually restrict what is sold. It is primarily a public-awareness, voluntary campaign to encourage people to NOT toss their AIS into lakes, ponds the oceans, etc.

2. Improve Coalitions and Network Partners

- Re invigorate AIS coalitions to better coordinate EDRR and to lobby for new approaches to increase resources: Example approaches
  - CaliWac: California Invasive Weeds Awareness Coalition – www.cal-ipc.org/policy/state/caliwac.php
  - BioSecurity: www.fao.org/biosecurity
  - NAISN (North American Invasive Species Network)
  - Use Special Districts (These often have more specific authority to act compared to state-wide governmental agencies): Regional Water Control Boards, Water and Sewer Districts, Resource Conservation Districts (RCD's)
  - Empower and fund the California Invasive Species Council: Can this Council form the basis for statewide EDRR with the diversity of new resources suggested? What is the current roadblock?
  - Re-define Aquatic weeds (and AIS in general) as "hazard" and "pollutant": Put an acceptable level at zero!
  - Balance levels of concern and the threats from impacts from AIS with adequate and proportional responses.
  - Re-examine how "restoration" projects are funded with regard to sustainability: Is adequate research and funding provided to stop AIS from negating restoration efforts in the "out- years"? Redirect "restoration" money so that adequate support is allocated to EDRR and sustained management of AIS.

3. Priority Target Aquatic Weed Species

- *Ludwigia* spp. (Water Primrose, Primrose willow groups): The group noted the rapid increase in populations of the genus *Ludwigia* in a range of aquatic and riparian habitats, including new infestations in some California rice fields.

- *Limnobium laevigatum* (South American Sponge plant). No sustained, state wide, coordinated and funded effort has being mounted yet. Some specific areas have been targeted (e.g. by CDFA and by chance by BWWS), but there has been no formal delineation of occurrence in the Sacramento-San Joaquin Delta.
- *Undaria pinatifida* – Marine kelp: This species has been expanding northward from earlier introductions in Santa Barbara and more recent introductions in Half-Moon Bay and San Francisco Bay.
- Multi-species strategies: Regardless of the "single" high priority species identified, unless there is an fully coordinated, holistic (landscape) scale approach taken where multiple invasive aquatic weeds persist, even the successful reduction or eradication of a few of those plants will simply allow the weeds of "lesser" impact to attain large populations and probably more detrimental impacts.

Recommendations:

The group suggested that CAL-IPC take the lead in championing one or more of the suggested solutions that emerged from this discussion. This effort could also be done in concert with both the California Invasive Species Council (or its Advisory Committee) and with the ANST/ Western Regional Panel.

Invasive Plant IPM (Integrated Pest Management)

Panelists: Matt Bahm, Sequoia-Kings Canyon NP; Joe DiTomaso, UC Davis; Ken Moore, Wildlands Restoration Team; Cindy Roessler, Midpensinsula Open Space District

Central ideas:

- Understands and uses biology and ecology of system.
- Environmental/human health and safety are of great concern.
- Do not necessarily have to use multiple treatment strategies, just the most safe and efficient method.

More thoughts:

- Usually utilize as many strategies to prevail against invasive plants.
- On larger scale, even using herbicides becomes a very useful tool.
- Control methods must look at plant seasonality, weather, and growth habit.
- IPM originated for ag and urban use, now wildland weed operations are the last to use.
- Efficiency is important: herbicide sometime most efficient and safe, depends on other feasible treatment options.
- Must be able to justify treatments.
- What method? Why? When? Where? All these questions come into play.
- Consider sensitive ecosystems.
- PPE for staff, and safely of park visitors is paramount.

"Intelligent Persons Method"

- Safety (no unnecessary harm done to people or planet)
- Effectiveness (goal is reached)
- Efficient (resources fully utilized)

Manager tools and forums:

- Go to www.cal-ipc.org/resources/listservs.php to sign up for the email lists.
- www.cdfa.ca.gov/plant/ipc
- www.ipm.ucdavis.edu
- wrc.ucdavis.edu

Herbicide Concerns:

- Companies need to take into account wildland application.
- Labels not written well, just what law requires.
- In some areas they are vaguely written to protect the companies.
- Pest Control Advisors may give different recommendations than land managers.
- Still use herbicides because they are cheaper than most other methods. Can be very effective in some situations.
- Need extremely well trained applicators

Biocontrol

- Often times, not the most effective, but can kill hard-to-find plants.
- In Australia, study says that for every $1 spent, $23 is saved.
- Planning and testing of biocontrol takes enormous amount of time.

Integrating the Student Chapter into Cal-IPC

Attendees: Students: Mike Bell (UCR), Kai Palenscar (UCR), Chelsea Carey (UCM), Meghan Skaer (UCD), Marit Wilkerson (UCD), Amy Concilio (UCSC)

Board Members: Doug Gibson (San Elijo Lagoon Conservancy), Julie Horenstein (California Department of Fish and Game)

Other: Heather Schneider (USGS), Sara Jo Dickens (UC Berkeley), Tony Summers (Catalina Island), Kyle Matthews (Habitat Restoration Services), Dean Tonenna (BLM)

Great discussions started at the student lunch and will continue here.

Mike Bell gives introduction to Student Chapter development and talks about how he thinks we should try to increase student attendance at symposiums.

- Purposes of SC are outreach, motivating students, as well at research and management activities, advocacy at the capital (e.g., WMA events, earth day events, etc.)
- UCR active membership is declining! (and has housed the bulk of the members.) Need to recruit and motivate new members
- Work on adding more info to website, activities, bringing in outside folks
- Student population ranges across most of the state (can depend on location of symposium).
- Now, one N and one S Cal student liaisons to the board (currently Chelsea and Kai)
- Creating connections: new universities, public, undergrads
- Outreach: speaker's bureau, outreach booths
- Speakers' bureau: someone with interest in invasive plants, will assign someone to go give a talk. Cal IPC provides a training Powerpoint. Can go to garden clubs, or native plant groups, etc.
- Debate about most recent updating – may be need to coordinate this
- Mike has idea to record AV to provide if a real person can't attend a particular group meeting.
- Networking:

  WMA: local land managers, $$ for travel, research

  Meet students, practitioners

Questions?

- Outreach to CSU Monterey Bay and UCSC? Yes! Two attended the lunch, and others from that area.

  Maybe someone with experience can go to speak with student at campuses with low representation. Lots of opportunities at UCSC, for example, as well as UCD. Also very motivated undergrad populations that could be tapped.

  Comment: WMA meetings – hard to know how to engage, what end goals?

  $$ they can provide is very valuable/useful. E.g., working to create new top-ten invasive plant list for the area (not enough staff, etc).

  How to approach them? Depends on WMA (new vs. more established), and location of WMA (money has to be spent in the county). Be assertive at first, and then maintain a presence.

  Found sites and made connections through WMA. Someone offered a job through a WMA associate
- What are other venues?

  UC ext., RCDs, watershed districts, local CNPS chapters. Sierra Club

  Put on a Web site – as examples of places to start in 'your region'.

  Fish and Game appointees, wide variety of uses for money. Would need to write grants (probably through Cal IPC as parent sponsor). National Wildlife Foundation small grants (ca. $5000)

- Need more student presence, especially undergrads
    - Need replacements for Cal IPC board, etc. Other groups to be involved in
    - Difference among students as to willingness to go to conferences (leave classes, etc.)
    - Need to make the connection with student early in their academic career. Through campus or regional student chapters. Perhaps through quarterly meetings, or similar. Could report back to co-chairs
    - What to talk about at local meetings?
        - Discuss local invasive species issues
        - Determine what outreach materials would be necessary for an event
        - Plan events
        - Discuss your research
        - Serve beer!
    - Similar to speaker's bureau – maybe the student chapter needs folks to come to campuses and talk to help get local branches started? I.e., Cal IPC representative
- How do we reach people?
    - Undergrad: junior and senior seminar – weekly meetings with speakers from the field to talk about grad programs or work options. Student chapter members could serve this function. Could speak in a number of different departments.
    - Utilize position as TA for undergrad classes. Marit mentions this as something that is working for other similar groups.
    - Orientation days, BBQs, etc. Booths on campus, usually have to be associated with campus (officially).
    - Develop relationship with professors who teach relevant courses and could talk about the group in class. Or build in a field component associated with student chapter.
    - One thing to talk about is just educating about invasive plants, or develop wide-appeal events (e.g. 'restoration days' 'trail days,' etc.).
        - Talk to local reserves
        - Event for wildlife restoration, brought together campus and community groups (rather than just one group at a time)
        - Partnering with other campus groups too

Student Presence in the Newsletter?

- How does the Cal IPC newsletter work?
    - Last we remember H. DeQuincy was in charge
- Do they have a need for articles? Have ideas for newsletter themes, but happy to get ideas for articles
- Could (re)institute a regular student chapter article?
    - E.g. highlighting events, could be helpful for partnering agencies, etc
- Need to followup with Heather/Elizabeth

How do we attract more students?

- Information about student events aren't broadcasted loud enough.
- Need to figure out how to outreach to other schools. Tried to contact professors, but didn't have much success – need to try again. Would be great to have at least one professor/advisor.
    - Maybe depends on what research is actually being done?
- Talking primarily to new academic board members, but other natural resource advisors would be good targets.
- Chico? Need faculty for real continuity at a given state campus. Extension professors should be major targets.

Thoughts on different things at the symposium for students

- One session for students for opportunities for careers.
    - This group has done that in the past.
- Advertise to undergrads, as a way to network, learn, get jobs. How to get a job at an agency, non-profit, etc. Even how to tailor your resume.
- Adopt-a-student Lunch. Join students and land managers with similar interests. Problems might be students don't know what they want to do, what the options are.
- Set up fund for travel scholarships. Southwest! For-profit companies.
    - Idea from earlier – fundraisers at symposia focused on creating student travel grants.
- You can't change symposium to weekend, because it would miss agency people, but it is usually Th/F/S instead of W/Th/F.

Student Grants/Training:

- Grant to help fund students going to conferences would be really helpful. Or just the lunch idea, to expand – one whole day where students do trainings, talks. E.g. CEQA, NEPA, permitting, etc.

Association of env. planners – not sure if they have a student chapter, but they do a lot regarding environmental regulation.

Planning and Conservation League is going to be offering training on env. reg.

Do you have trainings? And do you include student TAs? Maybe not – more formal certification program directed toward undergrad land managers for HCCP type areas.

Lots of professions that feed into this particular area – policy, finance, law, social. Intersection of environmental professions. Need lots of different backgrounds.

Job Shadowing

- Student perspective: we know how to learn, and how to be students – but wouldn't it be amazing to get shadow/mentors for a day. Know what we don't want to do but, not sure what we should do?
- Bring a grad (or undergrad) student to work day!
- Good to understand skills involved in management profession.
- Need a week at a job to get a good idea of what is actually going on!
- Agencies also have volunteer programs that provide workers comp protections, if needed.
- Good to work with groups to organize an effective weed event.
- Contact restoration companies – would be happy to host students. Might be more valuable than simply pulling weeds.
- SCA interns an example of this sort of situation.
- Immersion in the field has been really helpful for guiding education pursuits.
- Interested in where to find small research grants, to post on website. Include successful application files as examples. Student experience also valuable for large fellowships and grants.
- Any agency should be in favor of this. Try to see if there's someone who could serve as a contact person for this type of thing.

Idea to Improve Website

- We want a way to foster Inter-campus linkages.
- Cal IPC research needs assessments – two years ago. Posted on Cal IPC website. It should be more obvious to new students.
- Grants info could go on student Web site.
- Break up responsibilities by branch? Send out checklist, or suggest some items now?
- Add list of professors working in the field.
- Member info page – need at least names on the page, maybe contact info with permission.
- Publications page from Cal IPC students or past students who have presented at conferences.
- By the next symposium – release new student info site. Could write a grant for this?

TO DO:

- Cal IPC literature/research needs, listservs (MIKE)
- List of professors involved in invasive plant research (CHELSEA) – but folks will send ideas of people to Chelsea, set up survey monkey for this purpose.
- Grants: - survey monkey for this as well. (UC DAVIS)

  Small (by region) norcalbot, socalbot. Name, description, etc. – check Cal IPC Web site

  Outreach grants, USFW as source for smaller grants (but also really large grants, e.g. San Diego Foundation, Coastal Conservancy, SD River Conservancy – more flex, bond funds)

  Large – include examples from successful applications (EPA STAR, NSF GRF, DIGG)

  Look at T&E species grants in addition to invasive-focused grants. Or bird/wildlife grants (e.g. ducks unlimited).

  Board will look at the draft of the page.
- Follow up with someone on board for ideas for next symposium. KAI bring to December board meeting.
- Send out a symposium summary/outreach message.

Prevention Efforts Across the State: Weed-free materials and Prevention Best Management Practices.

Moderators: Wendy West, UC Cooperative Extension and Jen Stern, Cal-IPC

25 attendees

Prevention Team Update (Wendy West):

Sales of weed-free material are dependent on supply and demand. We need more people to start requesting weed-free material in order to get local producers to certify that their material meets those requirements.

YST Leading Edge Project is putting together a list of locations where one can buy certified weed-free material. The Team is currently asking producers where they are vending and so far have found 26 vendors. This list will be done in mid-November and a few organizations will be posting this list on their websites, including Cal-IPC and the CDFA Pest Exclusion Branch.

Comments

People are starting to charge for inspections of their material and inspections have dropped.

How would we update inspection procedures? We should look for funding for a formal inspection program. Pest Exclusion wants to make the in-field inspection process more rigorous and some agriculture commissions are working with their local governments to promote weed free materials.

Weed-free Memorandum of Understanding (MOU) Update (Bobbi Simpson)

The MOU is a commitment to incorporating weed-free material into everyday practices that agency representatives from USFS, BLM, NPS, DPR, CACASA, Caltrans, and CDFA signed. The language of the MOU has not changed much since the original came out, and extending the original one is being considered. MOU language is currently pretty loose, assuming the requirements will become more refined in the next phase. The biggest problems of maintaining the MOU is that there are not enough known vendors of weed-free materials. We cannot fulfill the MOU if we can't find the weed-free material. Agencies write Weed-free materials into their contracts (ie Caltrans), but this can be waived if weed free materials cannot be found.

Comments

It would be nice to see county and local governments say that they require weed-free materials, as this would definitely increase its demand.

Weed-free Gravel Project Update (Garret Dickman)

Educational materials are being readied in order to hasten buy-in from local land managers. The goal is to get Central Sierra land managers to agree to use weed-free gravel within the next year.

The gravel quarries themselves do not object to certifying their materials as much as do straw and bale producers, since reclamation of material should not contain infestations.

Comments

There has to be a clear communication of specific contract expectations. Should quarries have to provide pit condition details to agencies and then have agencies decide whether or not to use their materials from that assessment?

We must be careful about generalized inspections. Quarry conditions change from day to day, so cleanliness expectations must be based on sound research and widespread agreement. Right now, quarry conditions are based on subjective recommendations; there needs to be a liability of inspection. A formal inspection protocol is currently being explored by a few ag commissions.

The best idea so far is to outline a monitoring program in contract language in order to follow-up the condition of a certain site after using quarry materials.

Quarries are very cooperative. There is a need for more land managers to visit quarries and express their concerns of spreading weeds through quarry materials. It seems like there is a need for a trade association marketing certificate/sticker that advertises when materials have been deemed "weed-free."

"Weed-free" is a misleading term and can give people a false sense of security about the possibility of future infestations. Maybe should be changed to something along the lines of "weed-reduced." This needs more thought.

Prevention Best Management Practices (BMPs) for Land Managers Update (Jen Stern)

This is "version 1.0," a living document that can be updated with new BMPs in the future. The six chapters are based on common vectors of invasive plant spread. The "Project Materials" chapter-contains recommendations that agencies use weed-free material whenever possible.

Comments

Future versions of this document should include guidelines on how to determine which materials are weed-free and how to monitor areas where materials have been applied.