

Our Actions, Our Estuary  
9<sup>th</sup> Biennial State of the San Francisco Estuary Conference  
POSTER ABSTRACTS: Invasive Species

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

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Because invasive plants threaten San Francisco Bay's salt marsh plant communities, evaluating whether recently introduced species will spread rapidly can help managers prioritize conservation actions. Several populations of *Limonium ramosissimum* (Algerian sea lavender) were discovered in South San Francisco Bay in 2007. While this halophytic forb is invasive in southern California, whether *L. ramosissimum* is likely to spread by rapidly dispersing, recruiting, and reproducing in marshes across the Bay's salinity gradient, is unknown. We floated seeds at different salinities in aquaria to test effects on germination, and grew *L. ramosissimum* from seed to flowering under crossed inundation and salinity treatments in a tidal simulator experiment testing the potential for an estuary-wide invasion. Whether seeds floated for 1, 2, 4, 7, or 14 days or in 0, 15, or 30 salinity water, on average 86.7% of seeds across treatments germinated 16 days after being removed from aquarium tanks- indicating seeds have high dispersal potential. In the second experiment, after two months of *L. ramosissimum* growth in the tidal simulator, regardless of treatment, seedling mortality was extremely low (99.9% survivorship), however both salinity (0, 15, or 30) and inundation treatments (daily, bi-weekly or bi-monthly) affected growth. Plants grew 27 percent faster at salinities of 0 than 30, and 40 percent faster when inundated bi-monthly than daily, indicating while seedling survivorship is high across salinity and inundation gradients, plants will grow more rapidly both in the high marsh and further up-estuary where salinities are lower. *L. ramosissimum*'s potential to spread warrants early removal.

**Key Words** - *Limonium*; invasion; restoration; salt marsh

**Theme:** Invasive Species

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**Ecological Factors Contributing to Perennial Pepperweed (*Lepidium latifolium*) Expansion in Tidal Marshes of San Francisco Bay**

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Perennial pepperweed (*Lepidium latifolium*) is an invasive plant which successfully invades a variety of habitats including agricultural areas, riparian corridors, and tidal wetlands. The ecology of perennial pepperweed in upland areas and along riparian corridors is well-documented. However, less is known about the ecological factors that control perennial pepperweed expansion in tidal marshes. In tidal wetlands, invaded areas form dense, monospecific stands that can expand widely and eventually exclude other plant species.

We have been conducting detailed marsh vegetation mapping in South San Francisco Bay since 1989. This 20 year data set allows us to look at spatial patterns of perennial pepperweed expansion. Our research also examines factors influencing perennial pepperweed expansion, including salinity tolerance, variations in mean sea level and rainfall, microhabitat preferences within marshes, interspecific competition, and the role of levee slopes versus marsh plains in expansion.

With the anticipated restoration of over 15,000 acres of former salt ponds in South San Francisco Bay, the need for a better understanding of tidally invasive species such as perennial pepperweed is crucial to the successful restoration of native tidal marsh communities benefiting federally endangered species such as the California clapper rail (*Rallus longirostris obsoletus*) and the salt marsh harvest mouse (*Reithrodontomys raviventris*). Our research will enhance the ability of managers and restoration planners to identify ecological variables that facilitate perennial pepperweed invasions in tidal wetland areas. This information can then be used to prioritize control efforts in tidal marshes of San Francisco Bay and other tidal salt marshes.

**Key Words** - *Perennial pepperweed expansion in San Francisco Bay; marsh vegetation mapping in South San Francisco Bay; invasive species in tidal marshes*

**Theme:** Invasive Species

**Poster Board Number:** 47. Submission Number: 192

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**An Estuarine Copepod from Asia: Genetic Diversity in Two Recent Introductions**

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The estuarine copepod *Tortanus dextrilobatus*, native to estuaries along the coast of southern China, was first reported in Seomjin River estuary, South Korea and San Francisco estuary, USA in the early 1990s. The populations in these two estuaries are thought to have been introduced via ballast water. We obtained samples from these two introduced populations and from one population (Xiamen estuary, China) within the reported native range. We used mitochondrial DNA (cytochrome oxidase c subunit I) to compare genetic diversity in these native and introduced populations in order to test for source populations, test for reduced genetic variation within introduced populations, and determine whether multiple introductions had occurred. We found unexpectedly high haplotype diversity among all populations (86 haplotypes from 94 individuals). There were no shared haplotypes among the sampled populations and thus we cannot identify the source for either introduced population. There was strong bootstrap support for a clade formed by the Xiamen and Seomjin populations and also strong bootstrap support for the sub-clade formed by the Seomjin population. Most of the genetic variation (4% average sequence divergence) was between the San Francisco population and the group formed by the Seomjin and Xiamen populations. The Seomjin population had reduced nucleotide diversity in comparison with the Xiamen population, compatible with a founder effect. The San Francisco population, in contrast, showed no sign of reduced diversity.

**Key Words** - *invasive species; copepod; population genetics*

**Theme:** Invasive Species

**Poster Board Number:** 45. Submission Number: 211

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**Hiding in plain sight: distribution and genetics of morphologically cryptic hybrid *Spartina***

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*Spartina foliosa* is a valuable component of Pacific coast salt marsh communities. However, since the introduction of *Spartina alterniflora* from the East Coast, hybrid *Spartina alterniflora x foliosa* has become a noxious invader of the San Francisco Estuary, with the potential to degrade the quality of intertidal habitat for native plants, shorebirds and invertebrates. A major control program is underway and has made tremendous progress toward exterminating non-native *Spartina*. However, genetic testing of plants in five marshes revealed a surprising number of hybrid plants. The vast majority of these hybrids derived most of their genetic heritage from native *Spartina foliosa* and had a morphology indistinguishable from the native species. This raises the pressing questions of how the control program can exterminate plants that cannot be visually identified, and if such plants represent a serious problem for the health of estuary. Experiments in progress will characterize the ecological interactions and evolutionary potential of these cryptic hybrids, while new genetic methods are being applied to improve our ability to identify highly backcrossed hybrids.

**Key Words** - *invasive species; Spartina; salt marsh; intertidal, plant ecology*

**Theme:** Invasive Species

**Poster Board Number:** 48. Submission Number: 117

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**California Department of Fish and Game's Invasive Species Program**

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The Invasive Species Program at Department of Fish and Game has developed in recent years to include six staff at state headquarters, plus seven staff assigned to regional offices. The majority of these staff, including all regional staff, work solely on controlling the spread of quagga and zebra mussels. Of personnel remaining, one staff member is dedicated to invasive species issues throughout the Bay-Delta. Given limited resources and personnel compared to the size of the invasive species problem in California, the Invasive Species Program must prioritize and plan projects strategically.

The California Aquatic Invasive Species Management Plan, approved by the Western Regional Panel of the Aquatic Nuisance Species Task Force and signed by the Governor in 2008, guides a large portion of our work. This Plan provides a framework for how state agencies will coordinate with one another on aquatic invasive species issues and also addresses coordination with federal agencies, research institutions and stakeholders. It identifies and prioritizes 163 specific actions organized under the following eight objectives for the management of aquatic invasive species in California: coordination and collaboration, prevention, early detection and monitoring, rapid response and eradication, long-term control and management, education and outreach, research, and laws and regulations.

In addition to working on actions identified in this Plan, one of the program staff works on terrestrial weed management through participation in the California Interagency Noxious and Invasive Plant Committee, the Weed Management Area Advisory Council, and administration of a set of specially-funded weed management projects on DFG lands.

**Key Words** - *invasive species; fish and game*

**Theme:** Invasive Species

**Poster Board Number:** 53. **Submission Number:** 105

**Grazing Impact of the Overbite Clam on the Microzooplankton Assemblage of the San Francisco Estuary**

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The overbite clam *Corbula amurensis* has altered the San Francisco Estuary since its introduction in 1986. Feeding by *C. amurensis* is believed to be the cause of a substantial decline in phytoplankton biomass and in the abundance of some zooplankton species. Previous studies have demonstrated high feeding rates of *C. amurensis* on phytoplankton, bacteria, and copepod nauplii. To understand how *C. amurensis* affects pelagic food webs, we need to know what they are eating and how rapidly they feed. A potential source of prey not previously examined are microzooplankton, specifically tintinnid ciliates. Microzooplankton are defined as heterotrophic eukaryotes 20–200 µm in size, which includes copepod nauplii, rotifers, aloricate ciliates, and tintinnid ciliates. Microzooplankton provide a key link in pelagic foodwebs. They consume phytoplankton and bacteria, and in turn are eaten by mesozooplankton, >200 µm. The primary objectives of this study are to (1) quantify the current abundance of microzooplankton in the Low Salinity Zone of the San Francisco Estuary (salinity < 5) and (2) measure clearance rates of *C. amurensis* on microzooplankton, including tintinnid ciliates. Tintinnid abundance was monitored monthly at US Geological Survey water quality monitoring stations and compared to published data gathered before the clam was introduced. Preliminary estimates of clearance rate of *C. amurensis* on microzooplankton ranged from 173 to 444 mL ind<sup>-1</sup> h<sup>-1</sup>. This project will advance our understanding of the abundance of microzooplankton in the San Francisco Estuary and their role as a food source for *C. amurensis*.

**Key Words** - *Bivalve; Microzooplankton; feeding*

**Theme:** Invasive Species

**Poster Board Number:** 42. **Submission Number:** 97

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**Hybrid Assimilation in *Spartina*: Re-evaluating Conservation Goals**

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Hybridization between native and introduced species of *Spartina* (cordgrass) have significantly altered wetland habitats and created challenges for conservation in locations around the world. Since the hybridization between introduced smooth cordgrass (*Spartina alterniflora*) and native Pacific cordgrass (*S. foliosa*) was first documented in the San Francisco Bay, California, USA, in the early 1990s, we have witnessed the population explosion of invasive hybrids and the development of a genetically variable hybrid swarm. The California Coastal Conservancy's San Francisco Estuary Invasive *Spartina* Project (ISP) has systematically removed plants with obvious hybrid morphology or ecology as they work to eradicate invasive *Spartina* from the San Francisco Estuary. In the course of monitoring eradication efforts, we use genetic testing to determine the parentage of hundreds of cordgrass samples each year. The results of these genetic tests show that highly backcrossed hybrid plants, with no obvious morphological characteristics to distinguish them from natives, are "hiding" in the marshes of the Bay. Through the process of adaptive management, the ISP and the conservation community must now evaluate the extent of these "cryptic hybrids" and set realistic conservation goals based on the current and projected extent and consequences of hybrid assimilation.

**Key Words** - *Spartina*; management; wetland; marsh; restoration

**Theme:** Invasive Species

**Poster Board Number:** 49. Submission Number: 166

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**Evaluation of the Effects of the Herbicides on the Highly Endangered Lange's Metalmark Butterfly (*Apodemia mormo langei*)**

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The Lange's metalmark butterfly is in imminent danger of extinction due to the loss of habitat and food source, naked stem buckwheat (*Eriogonum nudum* var. *auriculatum*). These losses are primarily caused by invasive plants that significantly impact the few remaining acres of habitat at the Antioch Dunes National Wildlife Refuge. The use of herbicides is a common tool to control invasive plant species. Coincidentally, herbicide application occurs during the Lange's metalmark butterflies sensitive larval stage. Due to the lack of literature regarding butterflies and herbicide direct toxicity and the declines in native butterflies it is quite clear that a study evaluating the effects of herbicides on butterflies is necessary. We have evaluated the effects of several commonly used herbicides on a surrogate species, Behr's Metalmark. The effects of these herbicides on Behr's Metalmark will be discussed.

**Key Words** - *herbicide, butterfly, invasive species*

**Theme:** Invasive Species

**Poster Board Number:** 52. Submission Number: 250

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POSTER ABSTRACTS: Invasive Species

**Field Assessment of Bayluscide Treatments for the Control of New Zealand Mud Snails**

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The invasive New Zealand mud snail (NZMS) *Potamopyrgus antipodarum* was discovered in California in 2000 and has the potential to reach high densities, disrupt native food chains, and impact water delivery systems. The molluscicide Bayluscide (active ingredient: niclosamide) was tested in a concrete-lined irrigation canal in Solano County for effectiveness against NZMS. Test snails were exposed to niclosamide concentrations of approximately 1 mg/L for 8 or 17 hours. The results of this study indicate that almost complete mortality was seen in the treatments. The half-lives of niclosamide in water and sediment were 1.8 and 1.6 days, respectively.

**Key Words** - *bayluscide; niclosamide; New Zealand mud snail; invasive species; Potamopyrgus antipodarum*

**Theme:** Invasive Species

**Poster Board Number:** 43. **Submission Number:** 158

**Metabolic Responses to Environmental Salinity in the Invasive Clam *Corbula amurensis***

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The Asian or overbite clam *Corbula amurensis* is believed to have caused a large shift in the pelagic food web in the northern part of San Francisco Bay since its introduction in the 1980s. This shift is believed to be due to the clam's high density and filtration rates. We have investigated the metabolic responses of *C. amurensis* following acclimation to constant or fluctuating salinities. We measured growth rate, feeding rate, respiration rate, and activities of enzymes involved in metabolism and ion regulation in acclimated clams. On average, clams did not grow during a three-month period at either high or low salinity. Clams fed faster following acclimation to high salinity. Activity of malate dehydrogenase (MDH), an overall indicator of metabolism, did not differ significantly with respect to acclimation salinity, however means were higher at high salinity. In comparison to other bivalve species *Venus mercenaria* and *Venerupis japonica*, *C. amurensis* had significantly higher MDH activities. Activities of citrate synthase had a positive relationship with respect to acclimation salinity, suggesting higher respiration rates at higher salinities. Activity of Na<sup>+</sup>/K<sup>+</sup> ATPase, an ion regulation enzyme, may be higher following acclimation to elevated salinity, suggesting that the higher metabolic rates could be to support osmoregulation. Overall, our data suggest that clams experiencing higher salinities may have a higher metabolic demand and filtration rate, but put less of their metabolic energy into growth or reproduction.

Supported by CDWR-IEP grant to Wim Kimmerer and Jonathon Stillman.

**Key Words** - *Corbula amurensis*; salinity; clam physiology; invasive; san francisco bay

**Theme:** Invasive Species

**Poster Board Number:** 41. Submission Number: 149

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**Fouling-Related Practices of Vessels in California**

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Fouling of aquatic organisms to the submerged areas of vessels can be a major vector for the transfer of nonindigenous species (NIS), especially within the San Francisco Bay-Delta Estuary which received over 4100 commercial vessel arrivals during 2008. Introduction of NIS through vessel fouling can occur as organisms spawn, fall off, or are physically removed from the underwater areas of a vessel. However, the risk of NIS introduction through this vector is difficult to assess because of the limited amount of information on vessel practices that influence fouling accumulation. In order to fill this information gap, the California State Lands Commission (Commission) has developed a Hull Husbandry Reporting Form that all vessels operating in California must submit annually, as of January 2008. This reporting form is a ten-question survey aimed at gathering information related to practices that are likely to influence fouling extent on the submerged areas of vessels. These include hull husbandry practices, such as type and age of antifouling coating and length of time since the last drydocking or in-water cleaning, as well as certain voyage characteristics, such as traveling speeds and port residency times. A complete look at these fouling-related practices for all vessels operating in California during 2008 will be presented. These forms indicate that 97% of all vessels operating in California have been removed from the water for cleaning and treatment with antifouling coatings within the past five years, and 87% of those vessels have used an antifouling coating containing at least one biocide. The information gathered from this form over the next several years will provide detailed insight into characteristics thought to influence vessel fouling and will be used in conjunction with fouling-related research the Commission is currently funding to guide development of regulations governing the management of fouling on vessels operating in California.

**Key Words** - *Fouling; Nonindigenous Species; Invasive Species; Shipping*

**Theme:** Invasive Species

**Poster Board Number:** 39. Submission Number: 124

**Feeding and reproduction of *Acartiella sinensis*, an introduced predatory copepod in the Low Salinity Zone of San Francisco Estuary**

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The San Francisco Estuary is a highly invaded aquatic ecosystem, and most of the zooplankton community of the northern estuary are exotic species. *Acartiella sinensis*, introduced in 1993 from the Asian mainland, is a member of a common tropical-subtropical coastal genus. Although known by its morphology to be predatory, almost nothing else is known of this genus except for its spatial and temporal distribution. It is now one of the numerically dominant copepod species in the Low Salinity Zone (LSZ) in summer (3,000 individuals m<sup>-3</sup>). Recent declines in the abundance of several pelagic fish species in the LSZ have prompted further investigation into the foodweb of this region. Planktonic invertebrate predators can significantly influence the distribution and composition of their zooplankton prey; these predators therefore may play an important role in regulating community structure. We determined *A. sinensis* abundance and conducted the first experiments on its feeding and reproductive rates in an effort to understand its role in the LSZ foodweb. In our initial feeding experiments we examined predation on a very abundant, co-occurring introduced species, *Limnoithona tetraspina*. Preliminary results suggest that adult female *A. sinensis* will consume *L. tetraspina* nauplii (average ~25% of prey offered, or ~7 nauplii female<sup>-1</sup> d<sup>-1</sup>). Predation on *L. tetraspina* copepodites and adults was low and variable, suggesting these life stages may be less susceptible to predation by *A. sinensis*. The reproductive effort of *Acartiella sinensis* females averaged 13 eggs female<sup>-1</sup> d<sup>-1</sup> over 3 experiments. This moderate egg production rate is greater than those of the co-occurring calanoids *Pseudodiaptomus forbesi* and *Eurytemora affinis* (2-3 eggs female<sup>-1</sup> d<sup>-1</sup>), suggesting that *A. sinensis* may be supplementing its diet with prey other than *Limnoithona tetraspina* nauplii. This has implications for energy transfer to higher trophic levels, including declining fish species, in the region.

**Key Words** - *introduced species; copepod; zooplankton; predation; feeding; egg production*

**Theme:** Invasive Species

**Poster Board Number:** 44. Submission Number: 236

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**Birds and invasive plants: A review of interactions and management considerations**

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Invasive plants alter ecosystems in a variety of ways, most of which are assumed to be detrimental. Ecological effects are one of the criteria used by Cal-IPC to rate invasive plants; however, the effects of invasive plants on wildlife are unknown for most systems. During research for the 2006 Cal-IPC Inventory update, we found few published studies examining direct interactions between birds and invasive plants. For this poster, we reviewed available studies of the relationship between birds and invasive plant species in the San Francisco Estuary and Delta region. Available information ranges from qualitative observations to fine-scale GIS-based spatial modeling. We will summarize case studies representing a range of invasive plants and avian communities. For some species, strong data shows the negative effects of invasive plants on birds and the benefits of removing weeds. Other invasive plants appear at first glance to have a positive effect on measures such as avian density but may in fact be “ecological traps” that reduce the birds’ nesting success. In still other cases, the results are mixed depending on the avian species of interest. Understanding these interactions becomes increasingly critical as land managers and policy makers develop long-term plans to buffer wildlife species against climate change, plans that may include prioritizing which invasive plants to remove and where.

**Key Words** - *invasive species; invasive plants; birds; climate change*

**Theme:** Invasive Species

**Poster Board Number:** 51. Submission Number: 265

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**Continued Presence of the Chinese Mitten Crab in the San Francisco Bay and Delta.**

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The San Francisco Bay-Sacramento and San Joaquin Delta system has 234 known non-native species and potentially hundreds more. Once established, these species can pose a significant threat to threatened and endangered species (ANSTF 2005). One aquatic invasive species of concern in the Bay-Delta system is the Chinese mitten crab, *Eriocheir sinensis*. Shortly after its discovery in San Francisco Bay in 1992, the population increased until reaching an estimated peak in 1998 with a steady decline in population after this peak. Three surveys to investigate zoeae, megalopae, and juvenile abundance in the Bay-Delta have been conducted between 2007 and 2008. The purpose of these ongoing surveys is to determine the current status of the Chinese mitten crab population in the Bay-Delta and to test the efficacy of the monitoring methods. California Department of Fish and Game plankton tow samples taken from San Pablo Bay were analyzed for zoeae; light trap samples were deployed in areas of San Pablo Bay and analyzed for megalopae; and passive trapping for juvenile crabs occurred in south Bay tributaries. *E. sinensis* zoeae had the lowest abundance in 2007 and 2008. A total of six megalopae were caught in light traps during 2007 and 2008. No juveniles were captured in the passive traps deployed in south Bay tributaries. Reports of *E. sinensis* being captured as bycatch by fishermen and in scientific trawls have been rare in recent years. Although present in low numbers, the Chinese mitten crab is still found in the San Francisco Bay-Delta system. Information gained through continued monitoring and assessments of monitoring efficacy will be useful in developing effective early detection techniques and identifying potential population controls for this invasive species in the San Francisco Bay-Delta and other areas on the east and west coasts.

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**Poster Board Number:** 40. **Submission Number:** 179

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**Control and Management of Perennial Pepperweed Invasion: An Obtainable Goal?**

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Perennial pepperweed (*Lepidium latifolium*) is an aggressive, non-native weed that has invaded wetland and riparian areas throughout California, including the San Francisco Bay and Sacramento-San Joaquin Delta Estuary. At Rush Ranch, a brackish marsh in the San Francisco Bay National Estuarine Research Reserve, we applied a three-pronged approach to understanding and managing pepperweed: (1) mensurative experiments documenting impacts of perennial pepperweed on the sediment community and food web (2) eradication experiments evaluating efficacy and non-target impacts of herbicide control in a tidal marsh and seasonal wetland context, and (3) symposium series designed to bring together researchers and managers to assess and share the current state of knowledge regarding perennial pepperweed's ecological impacts, the extent of invasion in the greater Bay Area, and best practices for control. Within the high marsh zone, the presence of pepperweed significantly increased soil humidity and altered the diversity and composition of the surrounding plant, invertebrate and insect communities. We hypothesize that these changes will lead to cascading impacts throughout the entire food web. In mid and low elevations, the effects of perennial pepperweed are reduced due to constant inundation and soil saturation. In a seasonal wetland infested with pepperweed, we compared two herbicide treatments (Imazapyr and 2,4 D) applied to plots in May 2007 and monitored at 1 month, 6 months, 1 year and 2 years following application. Two years of 2,4D were not effective in controlling pepperweed but had minimal non-target impacts on the native plant community. Imazapyr reduced pepperweed cover by more than 90% compared to untreated controls, but non-target impacts on the native plants were severe and persistent. Our data provide important information about the consequences of perennial pepperweed invasion, about effective control techniques, and about developing an integrated and informed making process for perennial pepperweed control.

**Key Words** - *perennial pepperweed; invasive species; integrated management*

**Theme:** Invasive Species

**Poster Board Number:** 46. **Submission Number:** 147