Evaluating Effects of Fuels Treatments on Native Flora and Fauna: Restoration in Weed-invaded Landscapes of the Northern Rocky Mountains

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Study Overview

Noxious weed invasions threaten biological diversity, and weed control represents one of the greatest challenges facing land managers. Current management directives, including the National Fire Plan, call for the integration of weed control measures and management activities such as fuels reduction over vast areas. Chemical control methods represent a powerful tool, providing short-term suppression of target weeds at landscape scales, and broadleaf herbicides such as Picloram are increasingly used by land managers to reduce densities of noxious forbs in conjunction with management activities aimed at fuels reduction. Such management measures are often justified based on the assumptions that 1) suppression of noxious weeds will be beneficial to native components of the system, releasing native plants and animals from invader impacts, and that 2) despite any side effects of treatment, doing something is still better than doing nothing, i.e., allowing invasion to proceed. The ecological efficacy of management measures aimed at weed suppression must be critically evaluated to assure that efforts meet management goals.

We conducted a field study in western Montana (Lolo NF, Region 1) to improve understandings of treatment effects on native flora and fauna, building on a previously ongoing study that provided pre-treatment data as well as baseline understandings of species interactions. We originally proposed to examine the combined effects of prescribed burning and herbicide treatments in coordination with planned management activities on the Lolo NF. However, as explained previously (letter to Program Manager Bob Clark, June 23, 2003), although the herbicide portion of the treatment was successfully implemented as planned in fall 2002, burning treatments scheduled for spring 2003 had to be postponed by Lolo NF personnel in late March due to a shortness of funds and a narrow treatment window, which would have precluded treatment of all non-control sites. The positive aspect of postponing the burning treatments was that it has allowed us to study the independent effects of the herbicide portion of the treatment, which was not possible under the original design. Given that we observed strong effects of

herbicide treatment that were complex and persistent, we did not attempt to execute prescribed burning in the subsequent spring so that we could adequately capture the trajectory of herbicide effects (i.e., versus ending up with two incomplete studies examining potential treatment scenarios).

Study sites (6 ha in size) were steep, open-forest habitats of similar elevation (4400-5600 ft), aspect (south to west), and slope (average of 30%) that had either been invaded by spotted knapweed (*Centaurea maculosa*) or were dominated by native vegetation with only trace levels of noxious weeds. Spotted knapweed is an aggressive exotic species that covers vast areas of western North America and continues to spread. Over a 6-year period, we sampled plants and animals at knapweed and native sites, under two management scenarios: 1) no treatment, to evaluate the "no action" alternative, including the impacts of knapweed over time, and 2) weed control treatment using the broadleaf herbicide Picloram, to allow estimation of direct effects of herbicide application and indirect effects of knapweed suppression. Pre-treatment sampling was conducted 1999-2002 at 8 primary sites. In the fall 2002, 4 primary sites and 4 new sites received aerial application of Picloram at 1 pint/acre, while 4 primary sites and 4 new sites were left untreated to serve as controls. Each group included an even sample of knapweed and native sites to allow separation of knapweed removal effects from other treatment effects. Post-treatment sampling was conducted from 2003-2005, and JFSP funding was used to complete the last two years of data collection.

Spotted knapweed, a prevalent noxious weed in western North America.

Accomplishments

Our overall objective was to provide critical knowledge of treatment effects on native flora and fauna in the context of fuels management of the northern Rocky Mountains. Although we were unable to incorporate planned burning treatments into the study due to logistical constraints, we were able to focus efforts on broadleaf herbicide treatments, which are viewed as the primary weed control tool and very relevant to fuels management. Weed control measures must be considered in conjunction with fuels reduction treatments because disturbances such as fire and thinning are likely to facilitate weed invasion. In fact, current US Forest Service policy requires that management activities likely to promote the spread of noxious weeds include weed control measures, and current restoration initiatives such as the National Fire Plan call for integration of weed control measures. This issue is particularly relevant in the wildland-urban interface where treatments will be focused. In these open-forest habitats, fire suppression has increased the threat of wildfire, and noxious weeds are rapidly invading.

Towards our specific objectives, data were successfully collected to document treatment related changes in winter-range use of open-forest habitats by big game, quantify changes in small mammal and songbird communities induced by treatments, and describe treatment effects on plant and insect communities to evaluate habitat conditions for wildlife. This study was ambitious in its comprehensive approach involving numerous ecological components assessed at 16 study sites. Analyses of these data have ensued, and we have begun to distribute information

in the form of presentations, manuscripts, consultations with managers, tours, and a website. Preliminary findings to date are summarized below, and products, both completed and planned, are listed in Appendix 1.

Preliminary results

- Herbicide treatment provided temporary suppression of the target invader, spotted knapweed. Spraying of Picloram reduced canopy cover of this noxious forb by 80-90%, with suppression persisting through the 3-year post-treatment period. Because spraying was conducted in the fall, knapweed plants were killed and germination from the seedbank was suppressed prior to the primary growing season. This scenario may be especially compatible with spring burning, preventing response of knapweed to associated disturbance while maximizing longevity of suppression (Picloram persists in the soil for approximately 2 years following application). Although prevention and suppression of knapweed invasion should circumvent the negative impacts of this invader on native species, unintended effects of herbicide treatment must be considered as well to ensure that outcomes are truly in line with management goals.

- Herbicide treatment had adverse side effects on native perennial forbs, which in most cases, were not overcome by positive effects of knapweed suppression. Our prior research showed native perennial forbs to be particularly sensitive to knapweed invasion. This is especially problematic given that broadleaf herbicides such as Picloram damage forbs at the concentrations used in natural systems, and although they are selective to a degree, especially when applied in the fall when most natives are dormant, they are still known to damage native forbs. We devised an elegant analysis that allowed us to use fine-scale microplot data ($0.5m^2$ frames) to quantify the influence of pre-treatment conditions, including the level of knapweed invasion, on the treatment response, to evaluate the degree to which suppression of knapweed provided a positive "release" for native species and compare this to adverse effects of treatment.

Arrowleaf balsamroot, a prominent native forb sensitive to knapweed invasion and broadleaf herbicide treatments.

Our analysis showed that negative side effects of treatment reduced cover of some native forbs by >40% across the post-treatment sampling period. Release effects countered this decline to some degree, but only in areas with moderate knapweed invasion, and relief was significant only in the second year following treatment. We considered reproduction for one prominent native species, arrowleaf balsamroot (*Balsamorhiza sagittata*), and found that seed production and seedling density were also dramatically reduced, with no evidence of a counter release effect. In fact, due to treatment, abundance and reproduction of arrowleaf balsamroot in low invasion areas was reduced to levels typically found in high invasion areas. Although negative impacts should subside as Picloram residue is eliminated from the soil, knapweed will concurrently recover from its seedbank, replacing herbicide impacts with invasion impacts unless treatments are repeated. Therefore, if maintenance of native perennial forbs is a management goal, broadcast spraying of herbicides like Picloram may not improve the situation, and if applied to areas with only low invasion, may even worsen it.

● At the same time, native perennial grasses dramatically increased in response to herbicide treatment. Grasses are not directly affected by broadleaf herbicides such as Picloram. In fact, we showed that native grasses receive indirect benefits of treatment: suppression of knapweed and native forbs released this group from competition, which led to increases in cover of 40-100%. For the prominent native, bluebunch wheatgrass *(Psuedoroegenaria spicata),* cover and flowering in most cases were elevated above levels typically found in un-invaded habitats.

Just as native grasses were promoted by herbicide treatment, so were exotic grasses, particularly the problematic invader cheatgrass (*Bromus tectorum*). As with native grasses, at least some of the positive response of cheatgrass to treatment was related to suppression of spotted knapweed, which facilitated increases in cheatgrass cover of >100% and as high as 2000% in some cases. Cheatgrass replaced knapweed in areas invaded prior to treatment. However, cheatgrass also increased in areas with minimal levels of pre-treatment knapweed invasion, such that these areas became more "weedy" than they started. Whether or not this increase in cheatgrass is acceptable depends on management goals. Given that cheatgrass is known to exert strong negative impacts on natural systems, promoting invasion of this exotic grass is not desirable if goals include maintenance of native system function. For example, cheatgrass competes with native plant species, provides poor forage for wildlife species, and has been shown to increase fire intensity and frequency in Great Basin systems. Therefore, inadvertent promotion of cheatgrass through herbicide treatment may be too big of a cost in some cases, interfering with benefits of treatment such as native grass enhancement.

● Shifts in plant communities caused by herbicide treatment should affect habitat conditions for wildlife. Not only are linkages between plants and animals strong, but through our pre-treatment work, we have already seen how changes in plant communities induced by knapweed invasion can ripple through systems to impact consumers.

Suppression of knapweed, a strong interactor in the system, should therefore have repercussions for the system, as should other shifts in the plant community caused by herbicide treatment. Dramatic increases in native grasses should translate to a short-term increase in forage for grazing animals such as elk and deer. Analyses of data from pellet group counts will allow assessment of treatment effects on winter use of sites by these species.

Consideration of insects will also be crucial because they are a major food source for consumers like songbirds, and also provide a variety of services to plants, affecting the structure and composition of communities. The Orthoptera, consisting of grasshoppers and crickets, were the most abundant group sampled in pitfall traps on the sites. Analyses of pre-treatment data for >25 Orthopteran species indicated substantial sensitivity to knapweed invasion, especially for Cyrtacanthacridinae, a subfamily linked to perennial forbs. Therefore, effects of herbicide treatment on plant communities, including suppression of native forbs and promotion of native grasses, should lead to changes in composition of grasshopper communities.

Grasshoppers serve as a major food source for consumers like songbirds.

Furthermore, we showed that ground-foraging songbirds were negatively affected by knapweed related declines in food sources linked to prominent native plant and insect groups. Indicators of this effect included delays in breeding, and reduced productivity and fidelity of breeding adults

Chipping sparrow with color bands used to identify and track individuals. This species is sensitive to shifts in herbaceous plant communities via effects on food sources.

at knapweed compared to native study sites. If herbicide treatments increase food sources through indirect effects on native grasses and associated insects, songbirds may respond positively to treatments. Consideration of the timing of nesting will be especially crucial, given now documented impacts of knapweed invasion on this important component of reproductive success. Preliminary analysis of return rates of chipping sparrows from the season prior to herbicide application (2002) to the season following treatments (2003) revealed no immediate effects of treatment on site fidelity. However, our pre-treatment study, coupled with a large body of literature, suggests that return rates in a given year are driven primarily by the prior year's breeding success. Therefore, changes in resources induced by herbicide treatment would not be expected to affect site fidelity, as measured by return rates, until subsequent years.

- Due to complex interactions involving a biological control agent, herbicide treatment also caused native deer mice (*Peromyscus maniculatus*) to decline, restoring populations to levels more typical of un-invaded habitats. While most native species are adversely affected by knapweed invasion, our work has shown that deer mice attain unnaturally high populations in knapweed-invaded habitats due to the prevalence of two knapweed biological control agents (the gall flies *Urophora affinis and U. quadrifaciatis*). These control agents were introduced in the 1970's and provide mice with a superabundant food source, doubling and sometimes tripling populations in knapweed compared to native habitats. This is particularly problematic because deer mice are the primary vectors for the often fatal Sin Nombre hantavirus. Suppression of knapweed invasion via broadleaf herbicide treatment restored deer mouse populations to natural levels by removing the exotic food source, thereby minimizing hantavirus risk to humans. Maintenance of deer mouse populations at natural levels may be especially critical in the wildland-urban interface where human habitations and deer mouse populations readily interact.

Conclusions

Noxious weed invasion is a major issue facing land managers, determining the context for other management activities, including fuels reduction activities. Because such management activities are likely to facilitate weed invasion, particularly in the wildland-urban interface where seed sources are prevalent, weed control alternatives must be evaluated. Broadleaf herbicides are a powerful weed control tool, increasingly used to suppress certain noxious weeds over large areas. However, it cannot be assumed that incorporation of such weed control measures will improve ecological conditions per particular management goals, as adverse side effects of control tools may outweigh benefits of weed suppression.

We found that the broadleaf herbicide Picloram was successful in suppressing knapweed, and that some native plants, particularly bunchgrasses, responded favorably to removal of the target invader. However, in our study, treatment also promoted invasion of exotic grasses, and negative effects of herbicide on native forbs outweighed the benefits of knapweed removal for

this group. This is partially because plants in areas of low invasion received the negative effects of treatment without receiving many of the benefits of knapweed removal. Aerial application of herbicide will typically impact such native-dominated areas because of the patchy nature of weed invasion. Because suppression of noxious forbs by broadleaf herbicide is temporary, affected native plant communities are faced with either the impending return of the weed and its negative impacts or re-application of herbicide and the possibility for cumulative non-target impacts. Therefore, where mitigation of invader impacts is part of the management goal, aerial application of broadleaf herbicides such as Picloram may not produce the desired results. Instead, spot-spraying selected invaded areas may provide a management alternative that allows the removal of noxious forbs such as knapweed and the promotion of native grasses while minimizing non-target impacts on native forbs. The ultimate test of treatment efficacy in ecological terms will be the response of wildlife to associated changes in vegetation. In a timely manner, we will complete analysis of these data and finalize results in journal publications to provide a comprehensive evaluation of ecological efficacy of broadleaf herbicide treatments.

Appendix 1. Proposed products associated with the current study, including status.

Proposed	Delivered	Status
Presentations: public	Ortega, Y. K., and D. E. Pearson. 2005. Impacts of invasive species and associated control measures on the ecology of Mount Sentinel. Invited presentation for Five Valleys Land Trust. September, 2005. Ortega, Y. K., A. Benson, E. P. Greene, D. E. Pearson, and D. L. Six. 2007. Listening to the birds: what song can tell us about impacts of spotted knapweed invasion on natural systems. Bitterroot Audubon Society Meeting, Stevenville, MT. January, 2007.	Done, although additional presentations are planned.
Presentations: professional meetings	Ortega, Y. K, D. E. Pearson, K. S. McKelvey, and D. L. Six. 2004. Exotic plant invasion impacts breeding success and site fidelity of insectivorous birds. Ecological Society of America, 89th Annual Meeting, Portland, OR. August, 2004. Ortega, Y. K., and D. E. Pearson. 2005. Evaluating use of herbicide for restoration of native flora and fauna in weed-invaded landscapes of the Northern Rocky Mountains. Poster. Annual Meeting of the Joint Fire Sciences Program, San Diego, CA. November, 2005. Ortega, Y. K., D. E. Pearson, K. S. McKelvey, and D. L. Six. 2005. Ecological impacts of exotic plant invasions: a case study of knapweed and Chipping Sparrows. Invited presentation. Sheep, Goats, Weeds, and Wildlife Workshop. Missoula, MT. March, 2005. Ortega Y. K., and D. E. Pearson. 2006. From plants to songbirds: evaluating efficacy of herbicide for restoration of knapweed-invaded communities. Invited presentation. Montana Weed Control Association 2006 Annual Convention. Great Falls, MT. January, 2006. Ortega, Y. K., and D. E. Pearson. 2006. From plants to songbirds: evaluating efficacy of herbicide for mitigation of ecological impacts of exotic plant invasion. Poster. Invasive Species Research: Rocky Mountain Research Station Strengths, Needs, and Future Plans. Albuquerque, NM. March, 2006.	Done, although additional presentations are planned.

Presentations: professional meetings (cont.)	Pearson, D. E., Y. K. Ortega, and L. F. Ruggiero. 2004. Ecology and management of invasive species. Presentation to the USDA Invasive Species Council, Washington D. C. July, 2004. Pearson, D. E., and Y. K. Ortega. 2006. A conceptual framework for the research and management of invasive species. Poster. Invasive Species Research: Rocky Mountain Research Station Strengths, Needs, and Future Plans. Albuquerque, NM. March, 2006. Pearson, D. E., and Y. K. Ortega. 2006. Ecology and management of invasive species. Joe Skeen Institute for Rangeland Restoration - RMRS conference, Bozeman, MT. April, 2006. Pearson, D. E., and Y. K. Ortega. 2006. A conceptual framework for the research and management of invasive species. Poster. Joe Skeen Institute for Rangeland Restoration 4th Annual workshop. Cloudcroft, NM. September, 2006. Pearson, D. E., R. M. Callaway, and Y. K. Ortega. 2006. Ecological challenges of weed management in natural systems. Invited presentation for Weeds and their Management: A Problem for Wildlife? Special Symposium at the Montana Chapter of the Wildlife Society 2006 Annual Meeting, Helena, Montana. February, 2006.	
Publications	Jensen, J. M. 2005. Interactions between the invasive plant, Centaurea maculosa, and ant communities in savannas in western Montana. MS Thesis, University of Montana, Missoula, MT. Jensen, J. M., and D. L. Six. 2006. Myrmecochory of the exotic plant, Centaurea maculosa: a potential mechanism enhancing invasiveness. Environmental Entomology 35(2):326-331. Hansen, A. K. 2005. Effects of spotted knapweed invasion and restoration treatments on ground beetle diversity, abundance, and distribution in Rocky Mountain savannas in Montana. MS Thesis, University of Montana, Missoula, MT. Ortega, Y. K., and D. E. Pearson. *In review*. Efficacy of broadleaf herbicide for mitigating impacts of a strong plant invader in natural systems. Ecological Monographs. Ortega, Y. K., and D. E. Pearson. *In prep.* Response of ground foraging songbirds to suppression of a noxious weed via broadleaf herbicide.	Done, except where status is listed as "in review" or "in prep."

Publications (cont.)	Ortega, Y. K. 2005. Winter Range Restoration on the Lolo National Forest: Vegetation Response to Herbicide Treatments. Final Report to the Lolo NF. March, 2005. Ortega, Y. K., D. E. Pearson, K. S. McKelvey, and D. L. Six. 2005. Evaluating effects of herbicide for restoration of arthropod and songbird communities. Final Report to FS-PIAP. November, 2005. Copies have been widely distributed to managers. Ortega, Y. K., K. S. McKelvey, and D. L. Six. 2006. Invasion of an exotic forb impacts reproductive success and site fidelity of a migratory songbird. Oecologia 149(2):340-351. Pearson, D. E., R. Fletcher, and R. M. Callaway. *In review*. Herbicide treatments for weed control eliminate exotic food subsidies, returning native mouse populations to natural levels. Ecological Applications. Six, D. L. 2006. Effects of Forest Restoration Treatments on Songbird Prey. Final Report for Agreement between University of Montana and RMRS 04-JV-11222043-077.	
Tours	Ortega, Y. K. 2004. Field tour to study sites for Bitterroot Ecosystem Management Research Project coordinators Greg Jones and Sherry Ritter. June, 2004. Ortega, Y. K., and D. E. Pearson. 2005. Impacts of invasive species and associated control measures on the ecology of Mount Sentinel. Invited field tour for Five Valleys Land Trust. September, 2005.	Done
Training sessions & consultations	Ortega, Y. K., D. E. Pearson, and D. L. Six. 2005. Ecological impacts of exotic plant invasions and control measures: a case study of knapweed and Chipping Sparrows. Invited lecture to upperdivision Ecology Class, University of Montana, Missoula, MT. Ortega Y. K., and D.E. Pearson. 2006. From plants to songbirds: evaluating efficacy of herbicide for mitigation of ecological impacts of spotted knapweed invasion. Region 1 Training Academy, Missoula, MT. March, 2006. Pearson, D. E. 2006. Ecology of invasive species. Invited lecture to Wildlife Biology 370, Wildlife Conservation and Management, University of Montana, Missoula, MT. April, 2006.	Done, although additional sessions are planned.

Training sessions & consultations (cont.)	Pearson, D. E., and Y. K. Ortega. 2006. Consultation with Susan Rinehart, USFS Region 1, Assistant Regional Botanist, regarding use of broadcast application of herbicide as the primary weed control measure in the proposed EIS for the Lolo NF. Data on adverse side effects considered to promote cautious approach to aerial treatment of large areas with only spot infestations. September, 2006. Pearson, D. E., and Y. K. Ortega. 2006. The ecology and management of invasive species: a conceptual model. Region 1 Training Academy, Missoula, MT. March, 2006. Pearson, D. E., and Y. K. Ortega. 2006. A model for determining efficacy of weed control tools in relation to invader impacts. Presentation and discussion with Region 1 managers. October, 2006. Pearson, D. E., and Y. K. Ortega. 2006. Consultation with Steve Shelly, USFS Region 1, Regional Botanist, regarding use of broadcast application of herbicide as the primary weed control measure in the proposed EIS for the Lolo NF. Data on nontarget effects, particularly scale issues and promotion of secondary exotic species, will be incorporated into the analysis to enable improved implementation of herbicide use in line with management goals. November, 2006. Pearson, D. E., and Y. K. Ortega. 2006. Consultation with Mary Manning, USFS R1, Regional Ecologist, regarding application of research findings to current management measures, including efficacy of broadleaf herbicide use for mitigation of invasive plant impacts. December, 2006.	
Website	http://www.fs.fed.us/rm/ecopartner/farecent_papers.shtml Includes progress reports and related publications.	Ongoing