In this project, for example, the challenge of addressing water quality outcomes from wetland restoration was addressed by a dedicated subgroup of the strategy design team, who put in extra effort and consulted with other experts to create a practical approach. Another example was a pair of quick consultations in two watersheds to test an early version of the prioritization concept with prospective local users. Both process adjustments improved the emerging product and added confidence.

- *Land it safely*. Success is measured by the results, and in this case, that meant developing a strategy that could be adopted by decisionmakers. A great strategy won't make a difference if it doesn't get used. I created an effective pathway to approval and implementation by working across influential key stakeholders, populating the strategy design team with people who could influence final decisionmakers, and also working "up the food chain" with agency leaders throughout the project.

Early on, the strategy design team had to confront the persistent historical focus on restored acreage. An outcomes-based approach emerged during strategy development that allowed us to link new data and methods for identifying restorable wetlands with highly desired outcomes for water quality, habitat, and water supply. This allowed a critical shift from identifying acreage targets to identifying needed results. This outcomes orientation led to a relatively straightforward but sophisticated prioritization strategy that allows decisionmakers to evaluate potential wetland restoration sites against multiple benefit categories. After all, planners, managers, and policymakers want to know what functional benefits are most needed at a landscape, watershed, or flyway scale and to match those needs to restorable wetlands opportunities.

Participants believed that targeting water quality outcomes along with more established habitat outcomes was vitally important for the utility and credibility of the strategy, and they spent a great deal of time making water quality outcomes more accessible for prioritization. They also recognized that while groundwater interactions are also a potential priority, lack of data and limited resources prevented that factor from being included in the current restoration strategy.

This wetlands restoration strategy dovetails with the 2008 Minnesota Statewide Preservation and Conservation Plan (SCPP) that was developed around the same time (LCCMR 2008). The SCPP emphasizes the importance of prioritizing wetland restorations to achieve desired outcomes, and the newly created wetlands restoration strategy describes how to make prioritization a reality. In recognition of this significant step forward, the Minnesota Board of Water and Soil Resources adopted the "Wetlands Restoration Strategy: A Framework for Prioritizing Efforts in Minnesota" in January 2009, and implementation is underway (MBWSR 2009).

The strategy design team is not yet satisfied, however, and would like to see funding for a computer-assisted method that would be easier to use and would more easily incorporate localized information. What this current version does, however, is provide meaningful guidance for strategic decision making by a variety of government officials, land and water managers, and nongovernmental organizations—the kind of shared responsibility and shared accountability that characterizes "leadership for the common good."

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### Recommended Readings

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## Converting Pasture Land to Native-Plant-Dominated Grassland: A Case Study (Montana)

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Land is increasingly being removed from agricultural production, and in many cases, new landowners have management objectives not met by the plant species present. In other cases, weed species invade when agricultural practices are discontinued. Our study site was planted to introduced pasture grasses, flood irrigated, and grazed by cattle for approximately 70 years. The new landowner is interested in conserving the land for upland bird production, but the pasture grasses do not provide appropriate nesting habitat. Moreover, since landownership changed, annual grazing and irrigation have ceased, causing a decrease in pasture grasses and an increase in broadleaf weed species, particularly hoary cress (*Cardaria draba*) and Canada thistle (*Cirsium arvense*).

We investigated converting the site to native bunchgrasses and forbs, which would provide heterogeneous bunched, vertical structure for nesting cover in contrast to the existing pasture grasses, which form a homogeneous horizontal mat of vegetation after senescing. We use a successional framework for weed management that addresses the processes and mechanisms directing plant community dynamics (Sheley et al. 2006). Site availability refers to safe sites for germination of desirable species; species availability refers to the presence of propagules of desirable native species; and species performance is the measurable plant density and biomass. The specific objective was to determine the effect of various herbicide (to increase site availability and influence species performance) and seeding (to increase species availability) methods on the density of desired and undesired species.

The study site was located 88 km north of Missoula, Montana. The experiment consisted of a factorial combination of three herbicide and three seeding treatments arranged in a randomized complete-block design with four replications. Plots were 0.16 ha in size and were evenly burned prior to treatment application. The three herbicide treatments were 2,4-D (4.8 L/ha) plus Escort (metsulfuron-methyl at 70 g/ha); glyphosate (4.8 L/ha); and no herbicide. Escort and 2,4-D are broadleaf specific; glyphosate is nonselective. Herbicide was applied in April 2003 and June 2003 to coincide with the most effective times to spray hoary cress and Canada thistle, respectively. The three seeding treatments were drill, broadcast, and no seeding. The seed mix consisted of perennial native grasses and forbs of the rough fescue / bluebunch wheatgrass (*Festuca campestris* / *Pseudoroegneria spicata*) habitat type, which take one or more years to establish and flower, depending on the species. Seeding occurred in October 2003 at a rate of 11.5 kg Pure Live Seed per hectare for both drill and broadcast seeding treatments. Species seeded were bluebunch wheatgrass, 1.4 kg/ha; Idaho fescue (*Festuca idahoensis*), 0.5 kg/ha; rough fescue, 1.1 kg/ha; Sandberg bluegrass (*Poa secunda*), 0.2 kg/ha; blanketflower (*Gaillardia aristata*), 1.4 kg/ha; blue flax (*Linum lewisii*), 0.8 kg/ha; wild lupine (*Lupinus perennis*), 2.3 kg/ha; prairie sandreed

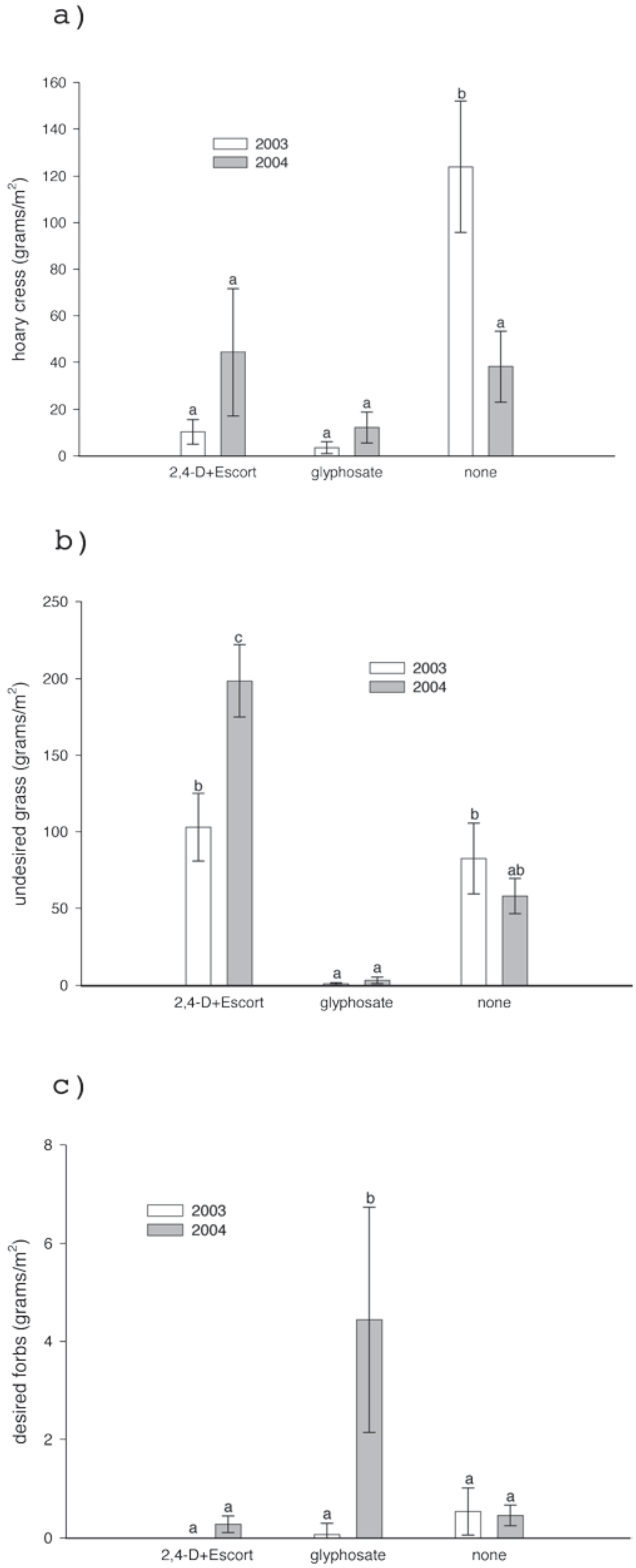


**Figure 1. Herbicide by year effect on mean (± SE) density of a) hoary cress; b) undesired forbs; and c) desired forbs in a former pasture north of Missoula, Montana, treated in 2003. Means with different letters are statistically different from one another ($\alpha$ = 0.05).**

**Table 1. Analysis of variance *p*-values and degrees of freedom (df) for main effects and interactions on plant density for treatments to convert pasture to native grassland north of Missoula, Montana; the model for desired grasses was nonsignificant.**

| Source | df | hoary cress | Canada thistle | undesired grasses | undesired forbs | desired forbs |
|---|---|---|---|---|---|---|
| replication | 3 | 0.3145 | 0.1455 | **0.0065** | 0.2394 | 0.1649 |
| herbicide (H) | 2 | **0.0008** | < **0.0001** | < **0.0001** | **0.0005** | **0.0048** |
| seeding method (SM) | 2 | 0.7514 | 0.0785 | 0.7409 | 0.5706 | **0.0068** |
| H × SM | 4 | 0.9939 | **0.0300** | 0.9257 | 0.4886 | 0.1195 |
| year (Y) | 1 | 0.5125 | 0.7711 | **0.0008** | **0.0028** | < **0.0001** |
| H × Y | 2 | **0.0004** | 0.3479 | 0.3729 | < **0.0001** | **0.0009** |
| SM × Y | 2 | 0.7492 | 0.6802 | 0.2791 | 0.2360 | 0.4797 |
| H × SM × Y | 4 | 0.9554 | 0.2181 | 0.3740 | 0.3045 | 0.3355 |

(*Calamovilfa longifolia*), 0.8 kg/ha; western wheatgrass (*Pascopyrum smithii),* 1.7 kg/ha; *and slender wheatgrass (Elymus trachycaulus),* 1.3 kg/ha.

We measured vegetative density in July 2003, 2004, and 2005 using five randomly located 0.5 m² frames per plot. For analysis, species were grouped as hoary cress, Canada thistle, undesired grasses (non-native grass species), undesired forbs (non-native forb species), desired grasses (seeded native species), and desired forbs (seeded native species). Analysis of variance was used to determine treatment and year effects on plant group density. When significant models were found, mean separations were accomplished using Tukey multiple comparison procedure at $\alpha = 0.05$ significance level.

Herbicide and year interacted to affect hoary cress (Table 1). The application of either herbicide decreased hoary cress density compared to the no herbicide treatment in 2003. By 2004 the herbicide effect had diminished in the 2,4-D + Escort treatment, and by 2005 all herbicide treatments had similar results (Figure 1a). Herbicide treatments provided temporary hoary cress control and may have increased site availability for seeded desirable species, but control may not have been long enough for desired plant establishment. Additional management may have been needed to continue to hinder hoary cress performance while desired species establish.

Canada thistle was affected by an interaction between herbicide and seeding method (Table 1). Mean Canada thistle density was highest when no herbicide was applied and the plots were either drill-seeded (3.7 plants/m²) or not seeded (2.4 plants/m²). The 2,4-D + Escort and glyphosate treatments by seeding method combinations resulted in similar Canada thistle density of about 0.2 to 0.5 plants/m².

Density of undesired grasses was affected by herbicide treatment and year (Table 1). Applying glyphosate resulted in the lowest density (averaging 8.0 tillers/m²), while the 2,4-D + Escort treatment displayed the highest density at 317 tillers/m². Mean density was highest in 2004 at 210 tillers/m² and lowest in 2003 and 2005 at 149 and 156 tillers/m², respectively. Applying a broadleaf herbicide appeared to release undesired grasses, possibly increasing competition for resources with seeded species. In contrast, the application of a nonselective herbicide killed undesired grasses and created sites for seeded species to establish. However, the herbicide effects appeared temporary, and site availability was not sufficiently long for desired species establishment.

Undesired forb density was influenced by the interaction of herbicide and year (Table 1). Density was high in the glyphosate treatment in 2004, but the no herbicide treatment in 2003 and 2004 produced similar densities (Figure 1b). The glyphosate treatment killed undesired forbs, but they reinvaded the site. Killing everything with a nonselective herbicide may be advantageous only if the site can be managed annually for undesired forbs until the desired species establish.

Because relatively few desired grasses seedlings survived to July 2004, the statistical model was not significant. Although we observed desired grasses emerging in the spring, especially where herbicide and drill seeding treatments occurred, their persistence may have been impeded by climate (ongoing drought), an increase in undesired species, or soil nutrient conditions. Soil tests indicated the site has elevated soil nutrients, presumably a result of past agricultural activities, that may perpetuate an early-successional weedy condition. Effective follow-up management may be needed to keep desired grasses from being overwhelmed by reinvading undesired species.

Desired forbs density was affected by the interaction of herbicide and year (Table 1). The glyphosate treatment in 2004 resulted in the highest density (15.9 plants/m²) of desired forbs (Figure 1c).

In summary, our study found that a broadleaf herbicide decreased hoary cress, Canada thistle, and undesired forbs. Glyphosate similarly affected hoary cress, Canada thistle, undesired forbs, and undesired grasses, which increased site availability for desired species establishment. However, the control of undesired species was temporary in both cases. Seeding increased species availability (propagules to occupy sites) of desired grasses and forbs, but only forb density increased over time, particularly where glyphosate was applied. Even though this study only occurred at one site, our results in conjunction with those of others who have tested successional management (Sheley et al. 2006, Fansler 2007) suggest restoring weed-infested lands using successional management may require repeated treatments to negatively impact performance of undesired species while promoting desired species. We are now testing additional mowing and herbicide treatments as part of an adaptive management strategy for the site. Mowing is aimed at decreasing the seed set of annual weeds and increasing light to establishing desired plants. Additional broadleaf-specific herbicides are being applied to suppress weed species while desired species establish. We are also investigating elevated soil nutrient levels as a potential cause of weed persistence.

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## Genetic Considerations in Ecological Restoration: An Annotated Bibliography

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The phenomenon of local plant populations being genetically adapted to specific sites can be significant in planning plant restoration work; the ability to evaluate genetic composition and diversity when choosing seed or plant materials from various sites can be an important tool. In restoration practice, there has not been agreement on how common population-level or local genetic adaptation may be and the significance it may have for survival and persistence. Further, for small populations of imperiled species, restoration planning has been concerned with genetic fitness of remaining populations and possible consequences of genetic drift and inbreeding and outbreeding depression. Moreover, there has been confusion in the land management community about whether seed or other material from distant sites is appropriate for use. How then to evaluate the relative merits and risks of matching material from the exact site, the next nearest site, the most similar habitat profile (which may not be the nearest site), or a mixture of material from many sites? Finally, climate change may affect the probability of persistence of restored populations and plant communities. The emerging concept of assisted migration and its effect on the survival of restored populations will require evaluation to ascertain both positive and negative consequences of mixing material from different sites, particularly under a rapidly changing climatic regime.

In an effort to centralize and highlight the importance of local genetic adaptation in restoration, the Center for Plant Conservation (CPC) has compiled a bibliography of resources (Box 1). The effort rose out of a need to help translate scientific findings into practical applications in the still relatively new practice of restoration biology. Applied biologists are not necessarily genetic specialists, but would still like guidance and fundamental background resources to help make the best decisions according to current restoration research. The bibliography will introduce land managers to the literature, including references that will help them choose appropriate plant source material and range of planting locations. The bibliography will also hopefully increase the chances of reaching restoration goals for those managers planning and conducting restoration work.

To compile the most useful literature review, professional population geneticists from universities, federal agencies, and botanic gardens were invited to attend two workshops. These workshops were organized and funded by CPC, with additional funding provided by the Bureau of Land Management. The meetings involved 10–11 participants and occurred on September 6–8, 2006, in San Diego, California, and September 14–15, 2006, in St. Louis, Missouri. Along with suggestions from workshop participants, the CPC Science Advisory Council, and the CPC network and partners, bibliographic search engines were used to compile the references, including Web of Science, JSTOR, FirstSearch, Google Scholar, and Google. The literature review includes not only peer-reviewed scientific articles, but also book chapters, conference proceedings, and governmental technical reports. Along with each citation, the author's abstract or summary is given except in cases where this was unavailable, and then a summary was written.

During the two meetings, two approaches to restoration surfaced in discussions, one focused on population-level, single-species restoration, and the other on larger-scale, community restoration projects. In addition, participants discussed how to best organize the literature review. The resulting product hopefully offers a range of possibilities for real-world scenarios and lays the foundation for practical yet sound restoration. The online bibliography sequentially presents 12 questions or topics that readers might be exploring (Box 1). Many of the 12 headings are divided into subtopics or examples that direct specific lines of inquiry under the broader topics.

The web site allows the user to search by these topics or by title, author, or keyword. The bibliography begins with a basic overview of "what is ecological restoration and why is it necessary?" that includes current articles introducing restoration as a practice and then explores why a manager or researcher might want to probe the topic further. The bibliography then launches into population