Upland Prairie Restoration Research at Wild Iris Ridge

2012

Final report to the Bureau of Land Management, Eugene District

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Institute for Applied Ecology

PREFACE

This report is the result of an agreement between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization whose mission is conservation of native ecosystems through restoration, research and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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Cover photograph: Shade and herbicide plots at Wild Iris Ridge summer 2010.

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REPORT TO THE BUREAU OF LAND MANAGEMENT, EUGENE DISTRICT

INTRODUCTION

Upland prairies in the Willamette Valley are among the most endangered ecosystems in North America, and support many imperiled species (Noss et al. 1995, Floberg et al. 2004). Wild Iris Ridge, a 228-acre natural area managed by the City of Eugene consists primarily of degraded remnant upland prairie (Figure 1). Although numerous native plant species occur at the site, invasive grasses such as tall fescue (*Schedonorus phoenix*), velvet grass (*Holcus lanatus*), bristly dogtail grass (*Cynosurus echinatus*), and forbs including false dandelion (*Hypochaeris radicata*) and oxeye daisy (*Leucanthemum vulgare*) dominate the community.

Figure 1. Wild Iris Ridge, City of Eugene

Recent research has suggested that repeated applications of herbicides combined with prescribed fire and seeding with native species can be effective at significantly increasing the cover and abundance of native plants, while decreasing that of introduced species (Stanley et al. 2008, 2010). However, multiple issues may inhibit the use of these tools. One of the primary restrictions is that the most effective treatment combination requires several years for full implementation, and may be too long and expensive for some restoration projects. Additionally, there is some concern regarding the use of herbicides in restoration due to their potential for non-target effects. Finally, it may be difficult to implement planned prescribed fires due to narrow burn windows and concerns about air quality and protecting neighboring property.

The purpose of this project is to evaluate site preparation treatments implemented in fall 2010 and management treatments implemented in June 2011 with the goal of informing restoration efforts in areas where management tools might be limited.

METHODS

Wild Iris Ridge, a 228-acre site composed of four parcels owned by the City of Eugene, is located along the South Hills ridgeline in Eugene, Oregon (Figure 2). This site contains a patchwork of oak woodlands, oak savanna, upland prairie, and riparian forest habitat. Habitat improvement activities at the site have included removing invasive species, thinning encroaching trees from oak savanna and upland prairies, and seeding the upland prairie with native plants.

Treatment Alternatives

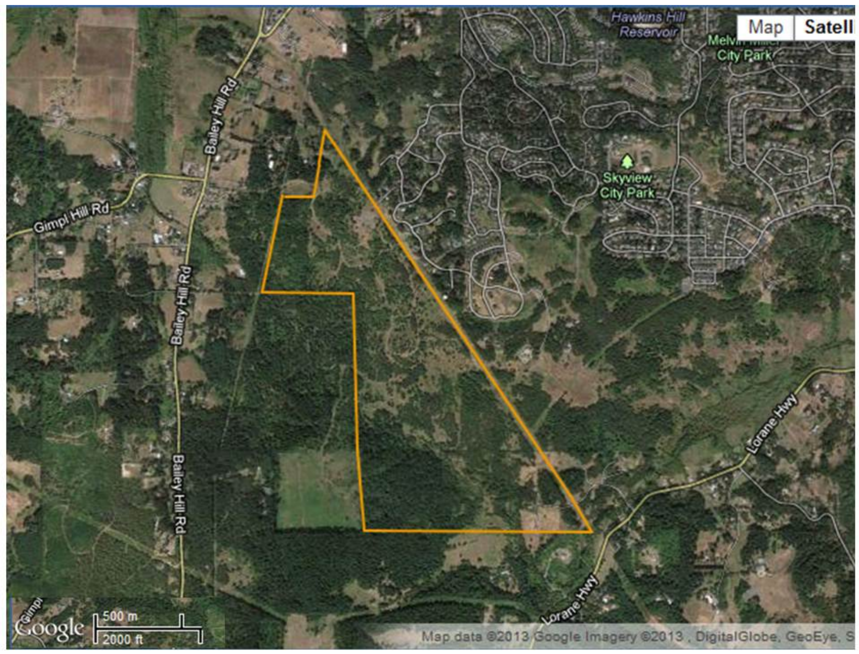

Figure 2. Wild Iris Ridge is located on the southwest edge of Eugene, Oregon.

IAE staff reviewed published and unpublished literature and consulted with the City of Eugene and other local experts to develop a background on the current best practices for upland prairie restoration in the Willamette Valley and identify knowledge gaps. The treatments recommended for this project were based on several long-term restoration projects in the Willamette Valley, including restoration in the West Eugene Wetlands (Pfeifer-Meister et al. 2007; T. Taylor, *personal communication*), in Wetland Restoration Enhancement Program sites (M. Blakeley-Smith, *personal communication*), and upland prairies in the Willamette Valley and Puget Trough (Boyer 2008; Stanley et al. 2008; Stanley et al. 2010, Thorpe 2010). IAE staff used this information to develop two site preparation and four management treatment alternatives. Plots were seeded after initial preparation.

In March 2010, we established four treatment macroplots at Wild Iris Ridge (Figure 3). Two of the blocks were divided in half due to space limitations (Figure 3). Blocks consisted of 8 5m x 5m plots, with1m buffers surrounding each plot. Buffers were mown at least once each year in order to minimize seed rain from neighboring vegetation. We utilized a split-block design in which half of each block (four plots) was assigned to either a shade cloth or herbicide site preparation treatment (see description below). The four plots within each preparation treatment were then randomly assigned one of four weed management treatments.

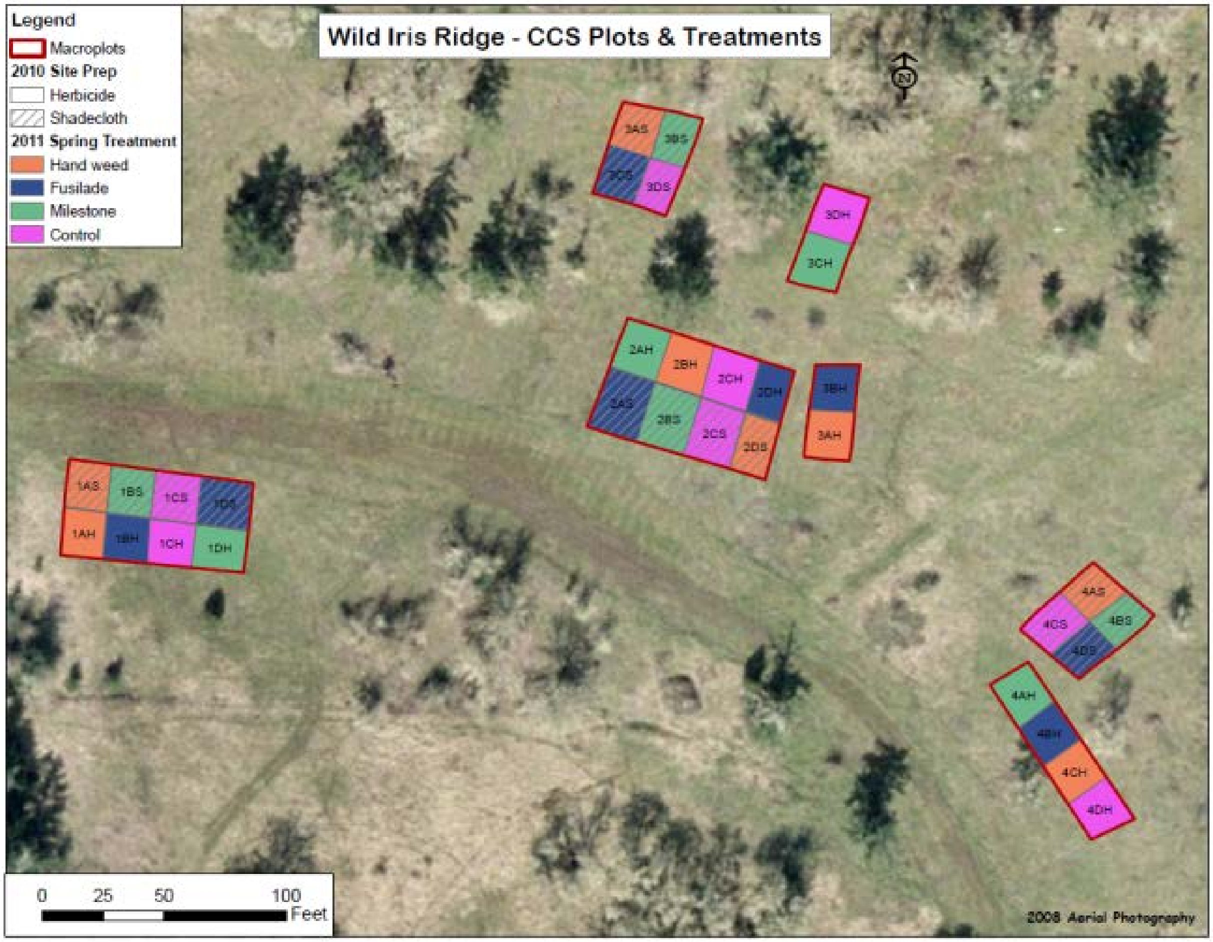

Figure 3. Block and plot layout at Wild Iris Ridge.

Site Preparation

Figure 4. Herbicide and shade cloth site preparation methods

We compared two methods for removing existing vegetation, herbicide application versus shade cloth (Figure 4).

• Herbicide application: This treatment involved applying glyphosate (4%) in early April 2010. There was good control of existing vegetation, but the treatment does not effect on the seed bank. Spot treatments with glyphosate in mid-summer and October 2010 were used to target vegetation that emerged after initial treatments. This is the standard site preparation treatment used in the Willamette Valley when conducting a restoration in which there is no need to maintain any existing plants.

• Shade cloth: Thick black shade cloth was applied to plots in April 2010. Before application, plots were mowed to reduce the height of existing vegetation. Shade cloth was removed in October 2010. This treatment was selected as an alternative to herbicide as it has the potential to kill all aboveground vegetation. Shade cloth can also kill seeds in the seed bank by increasing soil temperatures.

Seeding

Plots were seeded October 2010. The seed mix for the plots was composed of 32 native plant species found in upland prairies in the southern Willamette Valley (Table 1). All seed is from the Rivers to Ridges (WEW) grow-out program or the City of Eugene's native plant nursery, 2010 harvest when available, otherwise 2009 harvest.

We based species composition, including both grasses and forbs, on seed availability and future community composition goals, such as increasing nectar producing forbs. Forbs were included that have a variety of growth forms, growth rates, and 'functions' (e.g., geophytes, annuals, perennials, nitrogen-fixing legumes). We also included high species richness to fill niche space and compete with the variety of nonnatives present at the site.

We defined seeding rate by categorizing the species in the mix as either 'matrix' or 'diversity' species. 'Matrix' species were those that we had established in upland restorations in the area, or those that seem to be reasonable competitors. *Agoseris grandiflora* and *Lomatium utriculatum* didn't fully fit this model of matrix species, in that they are relatively untested in restoration activities, but were considered such for the purposes of this experiment. We defined 'diversity' species as those that we know are slow growing and/or very small when young or those that haven't established well in past restorations (e.g., *Camassia*, *Brodiaea*, *Koeleria macrantha*, *Asclepias speciosa*), but that are important nectar or matrix species in other situations.

Our overall seeding rate was a target of 15 lbs pure live seed (PLS) per acre of matrix species and 5 lbs PLS/acre of diversity species. The seeding rate was based on two primary considerations: we wanted a high rate for natives to establish, given that there was only one year of site pre-treatment, but the rate needed to be reasonable in terms of cost on a larger scale. Our seeding rate was higher than that typically used in prairie restorations that were former ryegrass fields or that have received more than one year of site pre-treatment to remove nonnatives. Use of higher seeding rate was based on our review of past research plots at Wild Iris Ridge that used high seeding rates (over 100 lbs/acre of seed), but were still heavily invaded by nonnative species.

Viability and purity results were available for most of the 32 species, and were used to calculate PLS values. Eight species were harvested in such small amounts that viability and purity testing were not done. Of these, for the Liliaceae, we reviewed past years' viability information and knowledge that the seed is typically very clean to arrive at an average PLS rate. For the five species for which we did not have a comparable or past rate, we made no adjustment for PLS (e.g., *Linanthus bicolor*, *A. speciosa*, *Danthonia californica*) and the mix contains the seed weight (as if 100% PLS).

To arrive at the seed rates for individual species, we used our experience with past restorations in the Eugene area (upland restorations at Coyote Prairie, Hayfield, Dragonfly Bend, Fir Butte). We considered past success in establishing these species from our accessions and knowledge of number of seeds per pound for the included species. No attempt was made to include the same number of seeds per species or the same weight of seed per species to each plot.

Management treatments

One plot within each split-block was randomly assigned one of three invasive species management treatments, or no treatment (control) (Figure 3). These treatments are:

• Hand weeding: Hand weeding can effectively remove introduced weeds while minimizing non-target effects. However, depending on the abundance of introduced weeds, hand weeding may be a relatively costly treatment.

• Fusilade: Fusilade is a grass-specific herbicide. Many of the most problematic weeds in upland prairies are introduced grasses, such as *Holcus lanatus*, *Schedonorus phoenix*, *Cynosurus echinatus*, and *Agrostis* spp. Although this treatment will negatively affect some of the native grasses at the site, the native Roemer's fescue (*Festuca idahoensis*) is resistant to Fusilade. Thus, it may be possible to control introduced grasses while having minimal impacts to seeded species.

• Milestone: Milestone is an herbicide that has the highest efficacy on forbs in the Asteraceae and Fabaceae families. Many of the most problematic introduced forbs, including *Hyphochaeris radicata* (Asteraceae), *Crepis setosa* (Asteraceae), *Crepis capillaris* (Asteraceae), *Cirsium* spp. (Asteraceae), *L. vulgare* (Asteraceae), and *Vicia* spp. (Fabaceae) in upland prairies are in these families. In contrast, many of our seeded species were in families that have more resistance to this herbicide. Thus, the intent is to achieve control of highly competitive invasives while having minimal effects on seeded species.

Broadcast application of Milestone and Fusilade II was simulated by setting backpack sprayers to the finest mist setting. Milestone was applied at a rate of 6 oz/acre, Fusilade II at 12 oz/acre. Treatments took from 1minute 45 seconds to 3 minutes per plot, averaging 2 minutes per plot. Care was taken to cover the entire plot while applying a similar volume of herbicide to each plot.

Two technicians worked side by side in each plot to accomplish the hand weeding. Given the density of both grass and forb target weeds, we envisioned a contract crew working in this way in a larger site (as opposed to one person per plot). Each plot was weeded for a total of 8 minutes (2 people x 4 min. each per plot). Although a significant number of weeds remained, devoting a longer period of time in each plot would have scaled up to be a much larger effort than would be practical. Time in the plot was split between grasses and forbs. In blocks where grasses were heavy (blocks 2 and 3), 2/3-3/4 of the time was spent on grass and vice versa for block 1, which was heavy with forbs. Shade cloth plots had an edge that did not get covered during site preparation. This area was not hand weeded, and time spent in these plots was reduced to 6.5 minutes total to keep the effort the same as in the plots prepped with herbicide. Species targeted during hand weeding were *H. lanatus*, *Cynosurus echinatus*, *Taeniatherum caput-medusae* (only found in Block 4 shade cloth) for grasses, and *H. radicata*, *Leontodon taraxicoides*, *C. capillaris*, *L. vulgare*, and *Cirsium vulgare* (only occasionally found in plots) for forbs. *Schedonorus phoenix* was too small to positively identify and *Briza minor* was so widespread that it would have taken all of the time allotted.

Plot buffers were mowed after the treatments. A high cover of *L. vulgare* was noted in the buffers during mowing.

Monitoring

Vegetation cover at all plots was monitored May 24-25, 2011, and May 23 and 30, 2012. Within each treatment plot, we defined a 4m x 4m potential sampling area within a 0.5m buffer. Plots were monitored by haphazardly placing a 1m^2 sampling plot near the center of the sampling area (Figure 5). This sampling method was selected due to its relatively low sampling time and amount of trampling within the plot. However, some species that occurred as individuals or in small patches in the plots were potentially missed. Species names and supplementary information follows the USDA Plants Database (www.plants.usda.gov).

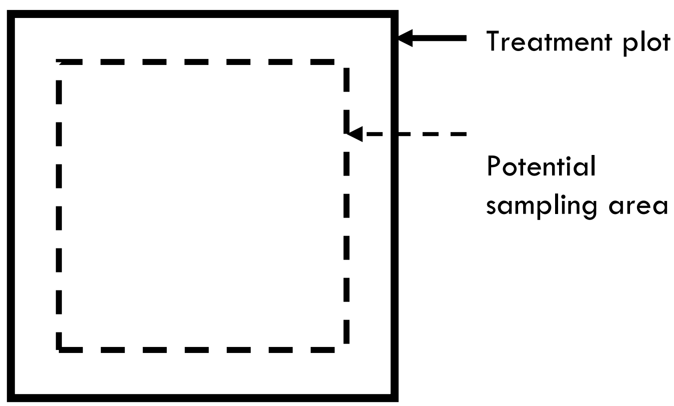

Figure 5. Sampling design at Wild Iris Ridge. A 1m^2 sampling plot was haphazardly placed near the center of each plot.

Table 1. Seed mix used at Wild Iris Ridge.

32 PLOTS; All identical

Species	Source	Yr	Seed needed per plot (g) - 2nd Calculation using plot size as % of acre	Total Needed for All Plots Combined (g) (x32)
Achillea millefolium	Her	10	0.8	26
Achnatherum lemmonii	Her	10	5.0	160
Agoseris grandiflora	PMC	10	1.4	45
Allium amplectens	Her	10	1.5	48
Asclepias speciosa	Her	9	2.3	74
Brodiaea elegans	BC	9	0.7	23
Bromus carinatus	Her	10	1.0	32
Camassia leichtlinii var. suksdorfii	Her	9	1.1	35
Clarkia purpurea quadrivulnera	Her	10	1.0	33
Collomia grandiflora	Her	10	1.2	40
Danthonia californica	PNN	10	4.9	158
Elymus glaucus	PNN	10	1.0	32
Eriophyllum lanatum var. lanatum	Her	10	4.8	154
Festuca roemeri	Her	10	5.2	165
Iris tenax	NPN	10	1.2	40
Gilia capitata ssp. capitata	Her	8	0.7	21
Koeleria micrantha	Her	10	7.2	231
Linanthus bicolor	Her	9	1.2	40
Lomatium nudicaule	Her	10	4.0	129
Lomatium utriculatum	Her	10	2.4	78
Lotus unifoliolatus var. unifoliolatus	Her	10	3.5	112
Lupinus polycarpus	Her	10	2.5	79
Luzula comosa	Her	10	0.8	25
Madia elegans	Her	10	0.8	25
Microseris laciniata	Her	10	2.1	66
Perideridia oregana	Her	10	2.6	82
Plectritis congesta	Her	10	3.9	124
Potentilla gracilis var. gracilis	Her	10	5.2	166
Prunella vulgaris var. lanceolata	NPN	10	1.9	60
Ranunculus occidentalis	Her	10	3.3	105
Sidalcea virgata	Her	10	5.5	177
Sisyrinchium idahoensis	NPN	9, 10	1.0	31
TOTAL			81.6	2615

Data analysis

Tests for treatment effects were conducted after final monitoring in spring 2012. We used permutation-based multivariate analysis of variance (PerMANOVA; Anderson 2001) to test the null hypothesis of no difference between the site prep and management treatment on plant community composition.

PerMANOVA is a non-parametric procedure for testing group differences much like parametric ANOVA, however statistical significance is based off of a pseudo-F ratio and permutation tests (McCune and Grace 2002). PerMANOVA allows for the use of Sørensen distance (Bray and Curtis 1957), which is a proportionate city-block distance measure often used in community analysis. PerMANOVA was run on a species matrix, using site preparation (shade cloth or herbicide) as the blocking variable and treatment (control, Fusilade, hand weeding, Milestone) as the grouping variable. Due to heterogeneity in the data set, rare species that occurred in 5% or less of the plots were deleted and species cover data was log(X+1) transformed to reduce skewness. When a significant main factor effect was found, we used a single factor PerMANOVA to test for differences in plant community for that factor.

We used a common ordination method, non-metric multidimensional scaling (NMS) ordinations (Kruskal 1964), to assess relationships of individual species cover relative to primary gradients in the plant community (ordination axes). NMS is an ordination method that is best used for community analyses, often with non-normal data with non-linear relationships (McCune and Grace 2002). We assessed species data relative to an environmental matrix with categorical variables indicating site prep and management treatment. NMS ordinations were performed using PC-ORD version 6.0 (McCune and Mefford 2011) with the autopilot setting "slow and thorough" mode, Sørensen distance measure, and no penalty for ties. We also summarized the native and introduced cover of major functional groups (forbs, grasses, shrubs) and cover of litter vs. bare ground for each site preparation and management treatment combination.

RESULTS AND DISCUSSION

Site preparation methods significantly affected plant community composition at Wild Iris Ridge (P = 0.0006, Table 2). Mean percent cover tended to be less in shade cloth plots than in those prepped with herbicide (Figure 6). Across all plots, introduced species had greater cover than native species (Figure 6, Figure 7), however the ratio of natives to introduced species in plots prepped shade cloth was greater than in those prepped with herbicide (66% and 61%, respectively), though this difference was not significant. In plots prepped with herbicide, introduced grasses composed the greatest percentages of cover, followed by introduced forbs (Figure 7). Native forbs and graminoids were similar in cover of herbicide prepped plots. In plots prepped with shade cloth, the greatest functional group abundance was of native shrubs (*Toxicodendron diversilobum*; poison oak); this was due to one plot with very high cover of the species. Introduced graminoids and forbs were the most abundant in shade cloth plots, but of native species forbs were the most abundant; native graminoids were not nearly as abundant in shade cloth plots as in herbicide prepped plots (Figure 7). Ground cover responded differently to the site preparation methods; those prepped with shade cloth tended to have greater cover of moss/lichen and bareground than those prepped with herbicide, however litter was greater in plots prepped with herbicide (Figure 8). We found no effect of management treatment on plant community (AppendicesAppendix B,Appendix CAppendix D). Likewise, there was no significant interaction between site preparation and management treatments (AppendicesAppendix BAppendix C).

The NMS ordination of sample units in species space (Figure 9) resulted in a 3-dimensional stable solution (final stress = 12.2, final instability = 0.000). A randomization test confirmed that final stress was lower than expected by chance (p = 0.05). Sample units prepped with shade cloth and herbicide tended to be separated in species space (Figure 9A), supporting the difference between site preparation methods found by the PERMANOVA. Sample units of different management treatments, however, were intermixed in species space indicating similarity in community composition between treatment types (Figure 9B).

Table 2. Single-factor permutation based multivariate analysis of variance (PerMANOVA) tests of the null hypothesis of no difference between site preparation methods.

	Df	SS	MS	F	*P*-value
Site Prep	1	0.39	0.39	2.77	**0.0006**
Residual	30	4.20	0.14		
Total	31	4.59			

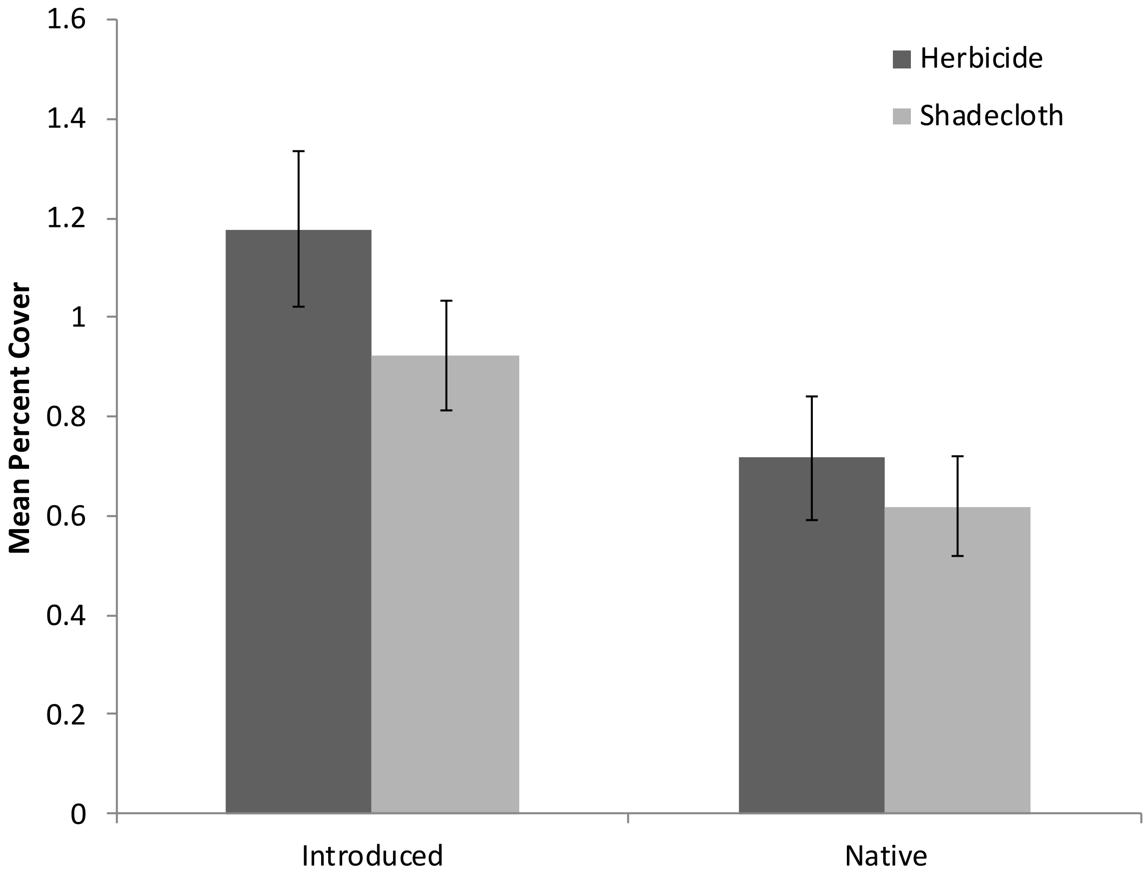

Figure 6. Mean cover of native and introduced species by site preparation treatment (herbicide or shade cloth).

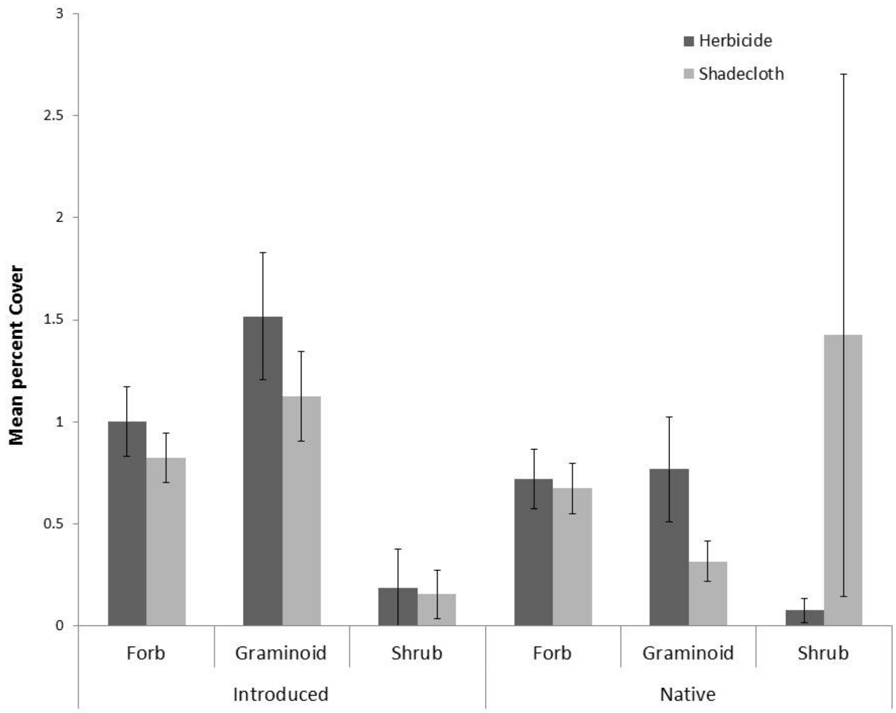

Figure 7. Mean percent cover of native and introduced species, sorted by functional groups, in plots with treated with site preparation methods (herbicide and shade cloth). Error bars are ± 1 SE.

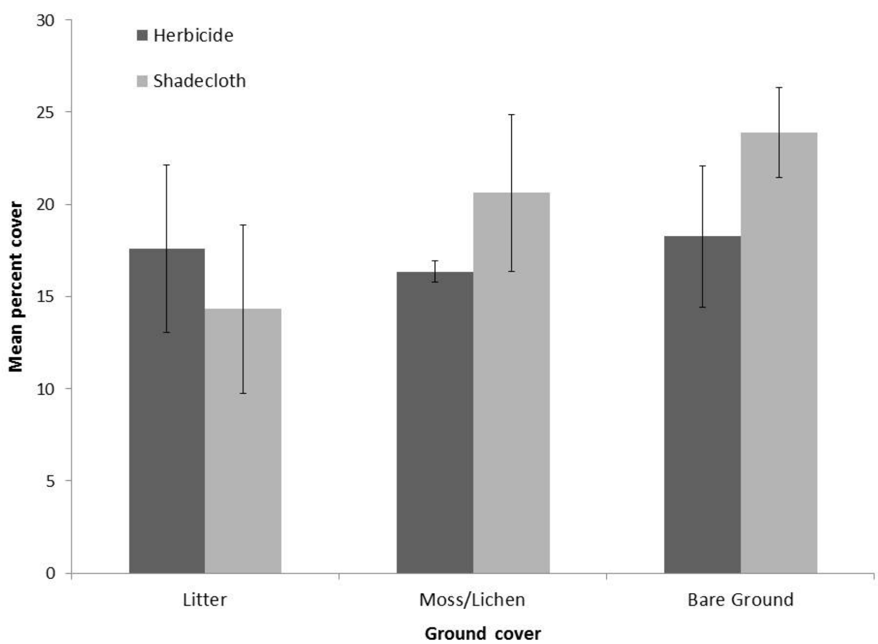

Figure 8. Mean percent cover of ground cover by site preparation method. Error bars are ± 1 SE.

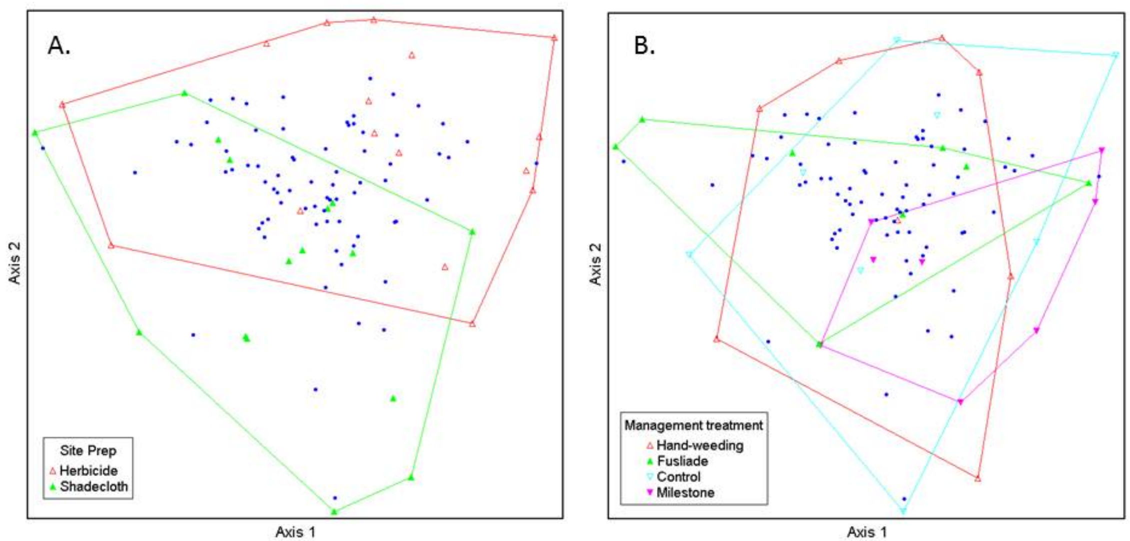

Figure 9. NMS ordination of community composition within plots at Wild Iris Ridge, comparing A. site preparation methods and B. Management Treatments. Triangles represent sample units in species space, and distance between points indicates similarity of community composition by plot. Colored polygons outline the extent of all of the sample units in each treatment group in species space. Blue dots indicate species and their locations in species space. Variance explained by Axis 1 was 20%, while Axis 2 explained 22% of the variance.

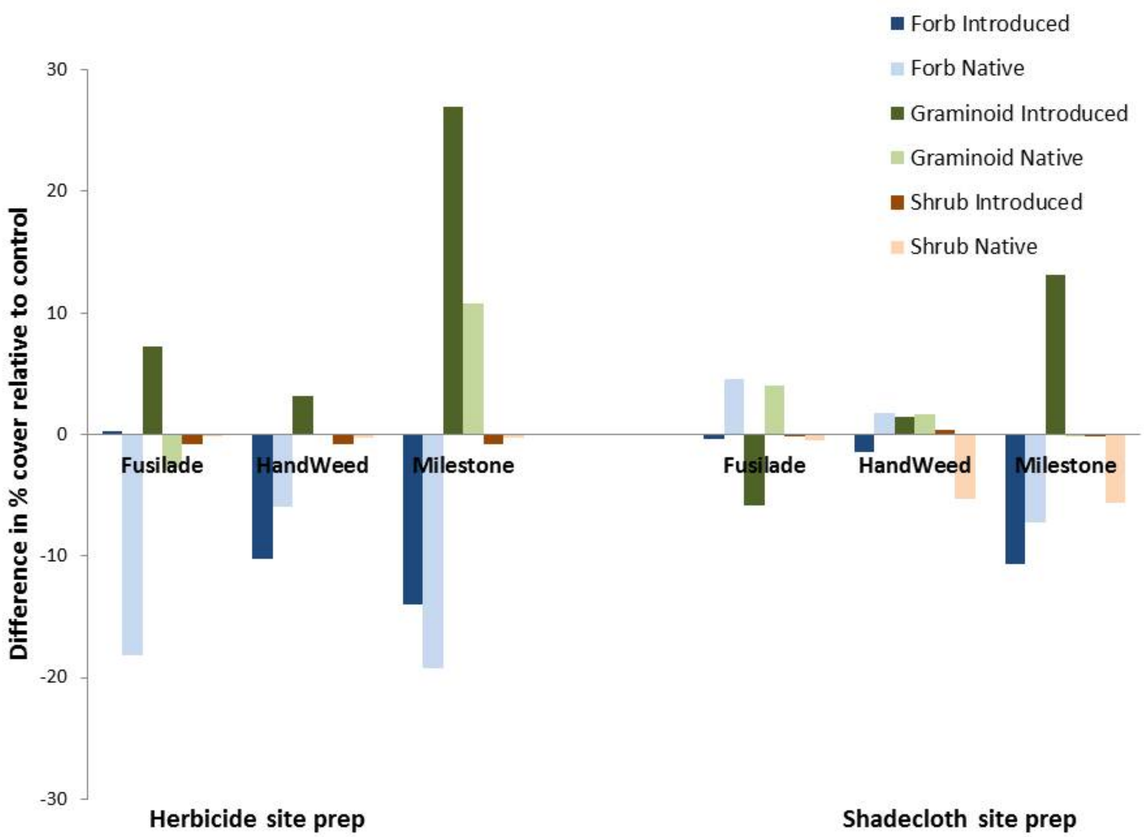

Figure 10. Difference in percent cover of species relative to the control in 2012

There was a high level of variability in cover of species and functional groups in our sampling plots relative to management treatments (Figure 10). Though treatment effects on plant community composition were not statistically significant, trends suggest that the plant community differed slightly in response to different management treatments, in comparison to control plots (Figure 10). In plots prepped with herbicide, native forbs tended to decrease with both Fusilade and Milestone. Native forbs tended to respond differently in plots prepped with shade cloth, where they decreased in those treated with Milestone but tended to increase in those treated with Fusilade. The response of these species was likely related to the difference in preparation effects on ground cover; those treated with shade cloth had more bare ground open for potential invasion. In plots prepped with herbicide, native grasses decreased slightly with Fusilade but increased substantially in plots treated with Milestone. In those treated with shade cloth, native grasses increased with both Fusilade and hand weeding treatments. As expected, Fusilade did not affect cover of introduced forbs. For both site preparation methods, introduced forbs decreased with hand weeding and Milestone treatments, however the effect tended to be greater in plots prepped with herbicide. In plots prepped with herbicide, introduced grasses tended to increase in all plots with the greatest increase in those treated with Milestone. For those prepped with shade cloth, introduced grasses decreased with Fusilade but increased substantially with Milestone.

Certain species were more abundant in plots with specific treatment types. As was expected, across both site preparation methods, spraying with a grass-specific herbicide resulted in higher cover of forbs, in particular introduced species *L. vulgare* and *Daucus carota.* Plots that were hand weeded also resulted in high abundances of *L. vulgare.* Plots treated with Milestone, a forb specific herbicide, had high abundances of introduced grasses including *Bromus hordeaceous, H. lanatus, Agropyron* sp., and *B. minor.*

While some seeded species responded more readily to certain treatment types, across all treatments certain seeded species had high establishment and survivorship. Native forbs including *A. millefolium, Plectritis congesta, Potentilla gracilis* var. *gracillis,* and *Ranunculus occidentalis* all increased percent cover from 2011 to 2012. Native grasses such as *Elymus glaucus, Festuca roemeri,* and *Danthonia californica* also increased in abundance. Some seeded species had minimal to no establishment including *Allium amplectens, A. speciosa, Iris tenax, Lomatium utriculatum, Lupinus polycarpus,* and *Peridieridia oregana* (Figure 11).

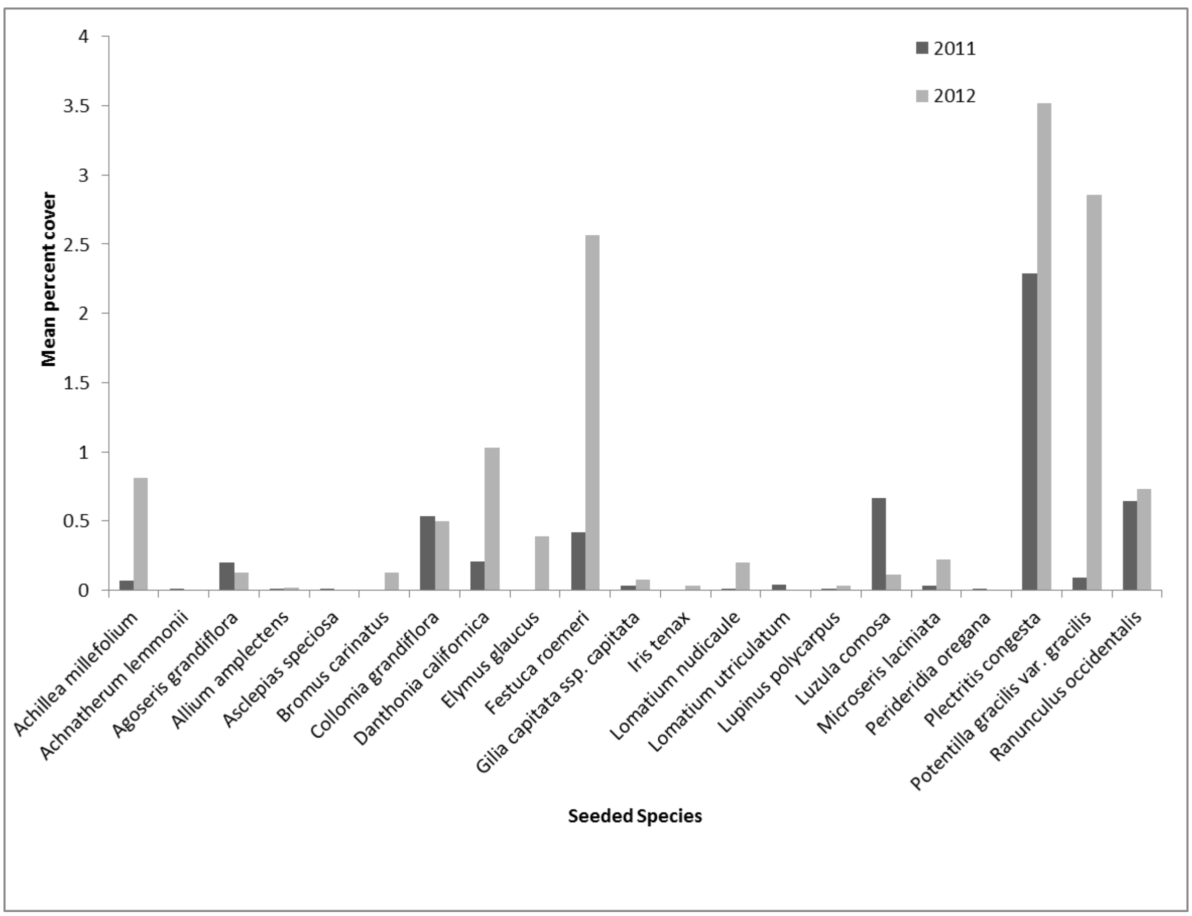

Figure 11. Mean percent cover of seeded species across all plots

This study demonstrates two site preparation methods that can significantly affect the resulting plant community in restoration of upland prairie habitats and are useful when other treatment alternatives, such as prescribed fire, are unavailable. Shade cloth reduced plant cover greater than herbicide site preparation, and the ratio of native to invasive species tended to be greater for shade cloth site prep than for those prepped with herbicide. Species tended to respond differently to management treatments following site preparation, though these responses were not found to be statistically significant. If shade cloth treatments are followed by a grass specific herbicide, the resulting plant community might have higher abundance of forb cover, however that forb cover could be composed of introduced species such as *L. vulgare*. Thus, with use of a grass specific herbicide, managers might be substituting a problem with introduced grasses with one of introduced forbs. Likewise, use of a forb-specific herbicide resulted in higher cover of invasive grasses, across both site preparation types. Though hand weeding enabled us to target non-native species, our results suggest that treatments did not result in a statistically different plant community; hand weeding might not be worth the relative cost of the treatment. This study identified seeded species that were particularly successful and should be considered in future restoration activities. Decisions regarding site preparation/management treatment combinations must take into account introduced species already present at the site that have a high likelihood of invasion.

For restoration efforts where goals are centered around increasing native species diversity, use of shade cloth as a site preparation method could be effective at creating a “blank slate” for seeding into; shade cloth as a site preparation method could be particularly useful when trying to increase native species diversity by creating “seed islands” (Reever Morghan et al. 2005), promoting new seed sources with potential to disperse into surrounding habitats. Future studies could focus on increasing the scale of these site preparation treatments and their applicability. Do site preparation methods significantly affect plant community composition on a large scale? Are these treatments economically feasible? Would use of a less diverse seed mix composed of primarily competitive plant species result in higher abundance of native species? Likewise, continued studies investigating other management techniques, such as carbon addition following site preparation, might enable us to increase understanding of treatments that might affect plant community composition.

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Appendix A. Species identified in sampling plots at Wild Iris Ridge, 2012. U.S. nativity and growth habit follow USDA plants database and local floras.

Species	Growth Habit	US Nativity
Achillea millefolium	Forb/herb	Native
Achnatherum lemmonii	Graminoid	Native
Agoseris grandiflora	Forb/herb	Native
Agropyron sp	Graminoid	Introduced
Agrostis sp.	Graminoid	Introduced
Aira caryophyllea	Graminoid	Introduced
Aira elegans	Graminoid	Introduced
Allium amplectens	Forb/herb	Native
Arrhenatherum elatius	Graminoid	Introduced
Asclepias speciosa	Forb/herb	Native
Briza minor	Graminoid	Introduced
Brodiaea sp.	Forb/herb	Native
Bromus sp.	Graminoid	Introduced
Bromus arvensis	Graminoid	Introduced
Bromus carinatus	Graminoid	Native
Bromus diandrus	Graminoid	Introduced
Bromus hordeaceus	Graminoid	Introduced
Bromus sterilis	Graminoid	Introduced
Camassia leichtlinii ssp. suksdorfii	Forb/herb	Native
Camassia quamash	Forb/herb	Native
Centaurium erythraea	Forb/herb	Introduced
Cerastium glomeratum	Forb/herb	Introduced
Cirsium sp.	Forb/herb	Introduced
Cirsium arvense	Forb/herb	Introduced
Clarkia purpurea ssp. quadrivulnera	Forb/herb	Native
Collomia grandiflora	Forb/herb	Native
Crepis sp.	Forb/herb	Introduced
Crepis capillaris	Forb/herb	Introduced
Crepis setosa	Forb/herb	Introduced
Cynosurus echinatus	Graminoid	Introduced
Dactylis glomerata	Graminoid	Introduced
Danthonia californica	Graminoid	Native
Daucus carota	Forb/herb	Introduced

Appendix A. continued

Species	Growth Habit	US Nativity
Dianthus armeria	Forb/herb	Introduced
Elymus glaucus	Graminoid	Native
Epilobium sp.	Forb/herb	Native
Eriophyllum lanatum	Forb/herb	Native
Festuca roemeri	Graminoid	Native
Fragaria virginiana	Forb/herb	Native
Galium aparine	Forb/herb	Native
Gamochaeta purpurea	Forb/herb	Native
Geranium dissectum	Forb/herb	Introduced
Geranium molle	Forb/herb	Introduced
Gilia capitata ssp. capitata	Forb/herb	Native
Grindelia integrifolia	Forb/herb	Native
Holcus lanatus	Graminoid	Introduced
Hypericum perforatum	Forb/herb	Introduced
Hypochaeris radicata	Forb/herb	Introduced
Iris tenax	Forb/herb	Native
Juncus sp.	Graminoid	Native
Koeleria macrantha	Graminoid	Native
Lactuca serriola	Forb/herb	Introduced
Lathyrus sphaericus	Forb/herb	Introduced
Leptosiphon bicolor	Forb/herb	Native
Leucanthemum vulgare	Forb/herb	Introduced
Linum bienne	Forb/herb	Introduced
Lolium perenne ssp. multiflorum	Graminoid	Introduced
Lomatium nudicaule	Forb/herb	Native
Lomatium utriculatum	Forb/herb	Native
lotus unifoliolatus	Forb/herb	Native
Lupinus polycarpus	Forb/herb	Native
Luzula comosa	Graminoid	Native
Madia sp.	Forb/herb	Native
Mentha sp.	Forb/herb	Introduced
Microseris laciniata	Forb/herb	Native
Myosotis discolor	Forb/herb	Introduced
Orthocarpus sp.	Forb/herb	
Panicum capillare	Graminoid	Native
Parentucellia viscosa	Forb/herb	Introduced
Perideridia oregana	Forb/herb	Native
Plantago lanceolata	Forb/herb	Introduced

Appendix A. continued

Species	Growth Habit	US Nativity
Plectritis congesta	Forb/herb	Native
Poa sp.	Graminoid	
Potentilla gracilis var. *gracilis*	Forb/herb	Native
Prunella vulgaris	Forb/herb	Native
Ranunculus occidentalis	Forb/herb	Native
Rubus armeniacus	Shrub	Introduced
Schedonorus phoenix	Graminoid	Introduced
Senecio jacobaea	Forb/herb	Introduced
Sherardia arvensis	Forb/herb	Introduced
Sidalcea malviflora ssp. virgata	Forb/herb	Native
Sisyrinchium idahoense	Forb/herb	Native
Sonchus asper	Forb/herb	Introduced
Stellaria media	Forb/herb	Introduced
Symphyotrichum foliaceum var. foliaceum	Forb/herb	Native
Taeniatherum caput-medusae	Graminoid	Introduced
Taraxacum officinale	Forb/herb	Introduced
Torilis arvensis	Forb/herb	Introduced
Toxicodendron diversilobum	Shrub	Native
Trifolium dubium	Forb/herb	Introduced
Trifolium microcephalum	Forb/herb	Native
Veronica scutellata	Forb/herb	Native
Vicia sp.	Forb/herb	Introduced
Vulpia bromoides	Graminoid	Introduced

Appendix B. Two-factor permutation based multivariate analysis of variance (PerMANOVA) tests of the null hypothesis of no difference between site preparation methods.

	Df	SS	MS	F	*P*-value
Site Preparation	1	0.39	0.39	2.77	**0.0002**
Management Treatment	3	0.53	0.18	1.28	0.09
Interaction	3	0.35	0.12	0.85	0.76
Residual	24	3.32	0.14		
Total	31	4.59			

Appendix C. Single-factor permutation based multivariate analysis of variance (PerMANOVA) tests of the null hypothesis of no difference between management treatment methods.

	Df	SS	MS	F	*P*-value
Management Treatment	3	0.53	0.18	1.23	0.14
Residual	28	4.06	0.14		
Total	31	4.59			

Appendix D. Photopoints of treatment plots monitored in 2012 (below)

Preparation: Herbicide; Treatment: Control

Preparation: Herbicide; Treatment: Fusilade

Preparation: Herbicide; Treatment: Hand-weeding

Preparation: Herbicide; Treatment: Milestone

Preparation: Shadecloth; Treatment: Control

Preparation: Shadecloth; Treatment: Fusilade

Preparation: Shadecloth; Treatment: Hand-weeding

Preparation: Shadecloth; Treatment: Milestone