CONTROLLING WOODY VEGETATION IN WETLAND PRAIRIES

1994-2001

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SUMMARY

Wetland prairies of the Willamette Valley, among the rarest of Oregon's ecosystems, are threatened by invasion of woody species and non-native pest species. Because fire has been important in maintaining Willamette Valley prairies for at least 1000 years, prescribed burning is a top choice of managers for preventing encroachment of woody species. However, the effects of prescribed burning on present day wetland prairie communities, with their mix of native and non-native species, are not clear. Moreover, because strict governmental requirements for smoke management hinder prescribed burning, natural-area managers are considering alternatives to fire, like mowing and hand-removal of woody plants.

The present study explored the ecological interactions of a wetland prairie by experimentally testing the responses of burning, hand-removal of woody species, and mowing with removal of cut material on woody plants and key native and non-native grasses and forbs. We evaluated these perturbations for their effectiveness in meeting management objectives of reducing abundance of woody species, reducing or preventing an increase in abundance of non-native pest species, and increasing or at least maintaining native species' abundance. After four treatments periods (1994, 1996, 1998, and 2000) the following patterns emerged:

- *Woody species* Burning and hand-removal of woody plants every two years consistently decreased the cover of woody species, even with a gradual increase in the controls to over double 1994 levels. The change in woody cover after mowing with removal of cut material was not significantly different from that in the control. As woody plant cover decreased, plant mortality increased, indicating that treatments influenced woody plant cover at least partially through changes in survival.
- *Native herbaceous species* None of the treatments had a significant effect after four treatment periods on the proportional change in cover or in number of inflorescences of *Deschampsia cespitosa*, although the change in number of inflorescences was consistently less than that in the control, including a significant decrease with burning in 1997. As a group, native graminoid species showed no significant differences in flowering response to treatments during any of the four treatment periods. However, burning and mowing consistently promoted flowering of *Juncus tenuis*. The cover of native forbs as a group was not significantly different from that of the control, with the exception of 1997, where cover increased with burning and hand-removal. Even though native forbs as a group have generally not shown significant differences, individual native forb species have shown positive responses to treatments: *Sidalcea cusickii*, spp. *purpurea*, *Eriophyllum lanatum*, and *Sisyrinchium idahoensis*.
- *Non-native herbaceous species* Both hand-removal and mowing promoted flowering of non-native graminoids as a group. In contrast, burning maintained levels of flowering of non-native graminoids similar to that of the controls. Cover of non-native forbs as a group showed no significant treatment differences except for 1997, in which significant reductions in cover occurred after burning and hand-removal.

The results to date show that prescribed burning is the best option of the three tested management treatments for achieving the restoration goals for native wetland prairies. Because mowing with removal of cut material was ineffective in reducing woody cover and tended to promote non-native herbaceous species, this treatment should be avoided.

INTRODUCTION

Native wetland prairies once dominated the landscape of the Willamette Valley of western Oregon (Habeck 1961, Johannessen et al. 1971). Before the mid-1800's the Kalapuya, indigenous people of the Valley, maintained these wetland prairies by setting periodic fires during the dry season, facilitating hunting and gathering of food (Boyd 1986, Boag 1992). These fires reduced the abundance of shrubs and trees, favored the abundance of native grasses such as tufted hairgrass (*Deschampsia cespitosa* (L.) Beauv.), and promoted a rich variety of native forbs. Today, however, less than 1% of native wetland prairies remain (Christy and Alverson 1994). These prairies are considered among the rarest of Oregon's ecosystems and are in critical need of conservation (ONHP 1983, Noss et al. 1995). Moreover, these remnants are refuges for many rare plant and animal species (Clark et al. 1993, Wilson et al. 1993, Wilson 1998).

Factors that contributed to the destruction of these unique wetland prairies include urban and agricultural development, threats that are also prominent today (Johannessen et al. 1971, Towle 1982, Hammond and Wilson 1993). When settlers in the early 1800's suppressed the large-scale fires by the Kalapuya, woody plants, such ash (*Fraxinus latifolia* Benth.) increased in abundance, eliminating suitable growing conditions for the prairie species (Habeck 1961, Johannessen et al. 1971, Towle 1982). Succession to shrublands and forests now threatens most of the few remnants of undeveloped prairie (Thilenius 1968, Johannessen et al. 1971, Franklin and Dyrness 1973, Frenkel and Heinitz 1987). In addition, weedy non-native species introduced with settlement have spread rapidly with habitat disturbance, often dominating and suppressing native vegetation (Nelson 1919, Wilson and Clark, in prep.).

This encroachment of woody species and invasion of non-native herbaceous pest plants are of great concern to agencies and managers responsible for conserving these remnant prairies.

Prescribed fire is a favored choice for management because of its historical role in the Valley (Johannessen et al. 1971, Towle 1982, Boyd 1986). Frequent burning for at least 1000 years has shaped the vegetation of these wetland prairies and returning periodic fire to the ecosystem is thought to aid in habitat restoration. Several concerns suggest caution before widespread adoption of fire as a prairie management tool. First, information on the effects of fire on wetlands is sparse, particularly in the western states, and lacks a comprehensive synthesis in contrast to the abundance of information on effects of fire in other ecosystems (Kirby et al. 1988, Schmalzer and Hinkle 1992, Kirkman 1995). Second recent invasion of wetland prairies by non-native plants has changed the context for fire. In fact, prescribed burning might promote seedling establishment of weedy, non-native plants as much or more than the native plants (Magee 1986, Streatfeild and Frenkel 1997, Maret and Wilson 2000). Third, strict governmental smoke management rules and variable weather conditions regulate when prescribed burning can take place, which may or may not coincide with historical timing of burning. Many remnant wetland prairies are now part of urban environments surrounded by roads, businesses, and homes, and thus, smoke, although temporary, becomes a significant concern for traffic and nearby residents (Agee 1996).

Because of these concerns, studies are urgently needed to understand the ecological interactions of these unique wetlands and to evaluate the efficacy of alternate management manipulations in controlling woody species and to evaluate the effect of these manipulations, including fire, on current native and non-native herbaceous vegetation. The goal of the present study was to determine, using an experimental approach, the effects of four management alternatives, prescribed burning, mowing with removal of cut material, hand-removal of woody species, and no manipulations, on wetland prairie vegetation. We used measurements of both pre-manipulation conditions and post-manipulation conditions in the analysis our data. The experimental design for the overall project (a replicated before-after-control-intervention design) gains its power from these pre-manipulation measurements.

METHODS

Study Site

Although the composition of the original vegetation of Willamette Valley wetland prairies remains somewhat unclear (Wilson et al. 1993, Streatfeild and Frenkel 1997), these seasonally flooded areas were probably dominated by bunchgrasses, particularly *Deschampsia cespitosa*. Other typical species may have included such graminoids as *Danthonia californica* Boland, *Beckmannia syzigachne* (Steud.), *Agrostis exarata* Trin., *Alopecurus aequalis* Sobol., *Eragrostis hypnoides* (Lam.) B.S.P., and *Juncus* spp. (Nelson 1919, Habeck 1961, Moir and Mika 1972). Today wetland prairie vegetation is characterized by a matrix of dominant grasses and sedges, interspersed with generally smaller-statured forbs (Wilson 1998).

This study was conducted on a remnant wetland prairie site (5 ha), located in west Eugene, Oregon (123° 10' 28"W and 44° 03' 05"), surrounded on three sides by heavily used city streets. The site contains several types of vegetation, including upland prairie vegetation dominated by the non-native species Scot's broom (*Cytisus scoparius* (L.) Link) and blackberry (*Rubus discolor* Weihe & Nees) and wetland prairie dominated by the native species tufted hairgrass (*Deschampsia cespitosa*) (Figure 1). Several *Carex* species, *Phalaris aquatica* L., and *Fraxinus latifolia* dominate the wettest areas (Figure 1). Two species on BLM's sensitive list are also present: *Microcala quadrangularis* and *Sidalcea cusickii* ssp. *purpurea*. A complete species list is found in Table 1.

The experimental plots were laid out in a section of high-quality wetland prairie dominated by *Deschampsia cespitosa*, but presently invaded by the woody species *Fraxinus latifolia, Rosa eglanteria* L., *Rosa nutkana* Presl, *Rubus discolor*, and *Crataegus douglasii* Lindl.

Experimental design and treatments

We used a replicated before-after-control-intervention approach with a randomized complete block design. Each of the five blocks was 22m × approximately 17m long, and contained four treatments: prescribed burning, mowing with removal of cut material, hand-removal of woody species, and no manipulations (Figure 2). The burn treatment areas were 8m wide, including a 1m buffer on each side. The purpose of the buffer was to reduce problems with edge effects. An additional mowed buffer (2m wide) was placed around the burn treatment for safety reasons. The other treatment areas were 7m wide, including a 1.5m buffer on each side. The length of the treatment area varied between 8m and 20m. Herbaceous plant responses were measured in three quadrats (1.0m × 0.5m) located randomly within each treatment area. Only those quadrats containing *Deschampsia cespitosa* were selected. Woody plant responses were measured either within the entire treatment area or in one-half of the treatment area, depending on density of woody cover.

The corners of each of the five blocks and the corners of the treatments within each block were marked by the BLM with green steel T fence posts (6 feet tall) for a total of 10 in each of the five blocks.

All treatments were applied in late summer or early fall of 1994, 1996, 1998 and 2000. Mowing was accomplished with a hand-held weed cutter. The mowed material was gently raked off the treatment area. Hand-removal of woody species was done using hand-held equipment such as pruners and loppers cutting the woody plants at ground level.

Measurements

Pre-manipulation data were collected June 17-July 2, 1994. Post-manipulation data were collected June 16-22, 1995, June 23-27, 1997, June 22-24, 1999, and June 25-28, 2001 when the community was at the approximately the same phenological stage as during the 1994 measurements.

The cover of shrubs and trees small enough to mow with a heavy duty weed-eater was measured within a treatment area. If the density of woody species was very high, the treatment area was subsampled by dividing the area into two cells, approximately 10m long. One cell was selected randomly for the cover measurement. This cell location was applied consistently to all treatments within a block. The cover of the woody species was measured as a group and not by individual species. Woody species included shrubs *Amelanchier alnifolia* Nutt., *Crataegus douglasii* Lindl., *Crataegus monogyna* Jacq., *Rubus discolor*, *Rubus laciniatus* Willd., *Rosa eglanteria,* and *Rosa nutkana* and the tree *Fraxinus latifolia*. In all estimates of cover, two investigators reached a consensus, using calibrated templates as standards.

Survival of woody species was determined by randomly selecting three shrubs in each treatment area, tagging the plants, and mapping their location in fall of 1994. Only shrubs that were isolated enough so that individuals could be distinguished were included in the random selection. Shrub species tagged included *Crataegus douglasii*, *Rosa* spp., *Rubus discolor*, *Rubus laciniatus,* and *Amelanchier alnifolia*. Three Oregon ash seedlings *Fraxinus latifolia* were also randomly selected in each treatment area, tagged and the location mapped. The survival of these tagged individuals (< 1 m tall) was recorded on post-manipulation sampling dates in 1995 only.

The herbaceous study species, all perennials, were selected because they were either rare species of interest or as a group they accounted for most of the herbaceous cover and could indicate the response of native and non-native species to the experimental manipulations. Nomenclature follows Hitchcock and Cronquist (1973).

Total herbaceous cover was measured within each quadrat along with the cover of each of the following species:

• Native forbs	*Sidalcea cusickii* Piper ssp. *purpurea*, *Eriophyllum lanatum* (Pursh) Forbes., *Veronica scutellata* L., *Lotus purshiana* (Benth.) Clements & Clements
• Non-native forbs	*Hypericum perforatum* L, *Centaurium umbellatum* Gilib, *Chrysanthemum leucanthemum* L., *Lysimachia nummularia* L., *Vicia sativa* L., and *Vicia tetrasperma* L.
• Native grass	*Deschampsia cespitosa*

The number of inflorescences of each of the following species was measured in each quadrat:

• Native forbs	*Sisyrinchium angustifolia* Mill.
• Native graminoids	*Deschampsia cespitosa*, *Carex unilateralis* Mack, *Carex densa* Bailey, *Carex feta/leporina*, *Carex* sp., *Juncus tenuis* Willd.
• Non-native grasses	*Holcus lanatus* L. and *Anthoxanthum odoratum* L.

Because quadrats without *Deschampsia cespitosa* were not measured, the cover values reported pertain only to the permanent quadrats and do not represent the treatment areas as a whole. That is, the sampling design aims to detect species changes within permanent quadrats caused by treatments.

Data Analysis

Treatment effects were calculated as proportional changes: the change in abundance with the manipulation, divided by the initial abundance. Using proportional changes as the response variable accounts for differences among areas in pre-manipulation abundance of the measured species. To avoid problems with zeroes in the denominator, cover data that were initially zero were transformed by adding 0.1 to the zero value before calculating proportional changes. The effects of treatments between 1994 and 1995 were then tested using analysis of variance (ANOVA) when the data met the assumptions of normality and constant variance, or when ANOVA assumptions were not met, the Freidman's Rank Sum test (SAS Institute statistical software, version 6.08) was used. For effects of treatments between 1994 and 1999 the Freidman's Rank Sum test was used for all analyses. Effects of treatments conducted in 2000 were analyzed using analysis of variance (ANOVA) (Statgraphics, version 5.0), using rank transformed data. Positive values show increases in abundances after the manipulation and negative values show declines. The significance level (α) was set to 0.10. If main effects were significant, differences between means were tested using Fisher's protected least significance difference.

RESULTS

Pre-manipulation community composition

Before treatment manipulations in fall 1994, woody plant cover ranged between 7 and 21% within the treatment areas (Table 2). Of the herbaceous species measured, *Deschampsia cespitosa* contributed the most cover, ranging between 15 and 22%. The average cover for the measured group of common native forb species ranged between 2 and 4%. *Lotus purshiana* was the most abundant native forb. The average number of inflorescences for the measured group of common native graminoid species was about 10 to 13, with *Deschampsia cespitosa* producing the highest average (Table 2).

The average cover for the measured group of common non-native forb species ranged between 1 and 6% (Table 2). *Hypericum perforatum* and *Vicia tetrasperma* were the most consistently abundant non-native forbs. *Lysimachia nummularia* had the highest abundance of any forb within a single treatment area, but was found only in block 2. The average number of inflorescences for the measured group of common non-native graminoid species was about 5 to 14. *Anthoxanthum odoratum* and *Holcus lanatus* both had similar average number of inflorescences. However, *Anthoxanthum odoratum* was much more variable, reflecting its patchy distribution on the site.

Average overall herbaceous cover within quadrats ranged between 35 and 39% (Table 2). *Deschampsia cespitosa* cover accounted for approximately half of this overall cover. Because quadrats without *Deschampsia cespitosa* were not measured, the cover values reported in Table 2 pertain only to the permanent quadrats and do not represent the treatment areas as a whole.

Effects of experimental manipulations

Woody species. Through treatments in fall 2000, burning and hand-removal of woody plants significantly decreased the cover of woody species compared to the control plots (Table 3). The change in woody cover after mowing with removal of cut material was not significantly different from that in the controls (Table 3). This pattern of woody response to treatments has remained consistent since treatments began in 1994 until the present year 2001 (Table 3).

Repeated burning and hand-removal every two years for six years has not increased the original 91% reduction of woody cover in 1995 (Table 3). The proportional increase in woody abundance after mowing has also remained relatively consistent throughout the treatment period with the exception of a decrease in 1995. Woody cover has gradually increased in the controls to over double 1994 levels (Table 3).

Survival of woody species, measured only the first year after treatment, showed that significantly fewer shrubs survived burning compared to the control (Table 3). In contrast, survival with hand-removal and mowing were not significantly different from the control.

Native herbaceous species None of the treatments had a significant effect on the cover of *Deschampsia cespitosa* compared to the control in 2001, a pattern, which is consistent with the pattern of the previous four treatment periods (Table 4). The proportional change in the number of inflorescences of *Deschampsia cespitosa* in each of the treatments in 2001 was less than that of the control, although not significantly so (Table 4). This pattern of reduction of *Deschampsia cespitosa* inflorescences with treatments was generally repeated in previous years, including a significant decrease with burning in 1997 (Table 4). In contrast, burning, along with mowing, significantly increased the number of inflorescences of *Juncus tenuis* in 2001 compared to the control (Table 4). These two treatments have consistently promoted flowering in *Juncus tenuis* during all four treatment periods (Table 4).

In 2001, hand-removal of woody species significantly decreased the number of inflorescences of *Carex unilateralis* and burning increased the number of inflorescences (though not significant statistically), following a pattern initiated with the previous treatment period 1998-1999 (Table 4). Burning also promoted flowering of *Carex densa* compared to the controls after every treatment period, although the increases are not statistically significant (Table 4). As group, however, native graminoid species showed no significant differences in flowering response to the treatments during any of the four treatment periods (Table 4).

The cover of native forbs as a group in 2001 following management treatments was not significantly different from that of the control, which has been a consistent pattern after all four treatment periods, except for 1997. The two species chiefly contributing to this group increase in

1997 were *Lotus purshiana*, with burning and hand-removal relatively promoting cover compared to the controls and *Veronica scutellata*, with hand-removal and mowing significantly increasing cover (Table 5).

Even though the native forbs as a group have generally not shown significant differences between treatments and the control, individual native forb species have shown positive responses to treatments. *Sidalcea cusickii* spp. *purpurea*, listed as a BLM sensitive species, showed an increase in cover for the first time with treatments (mowing) in 2001 (Table 5). *Eriophyllum lanatum*, which was previously absent in the burn treatments, appeared for the first time in a burn treatment in 1999 and increased in cover in 2001 (Table 5). *Sisyrinchium idahoensis* flowered for the first time in the mow treatment in 1997 and for the first time in the burn treatment in 1999 (Table 5). The lack of proportional change in number of inflorescences of *Sisyrinchium idahoensis* in previous years was due to its absence in the sampling plots. It has continued flowering in 2001 in the burn and mow treatments, although with no significant differences between treatments (Table 5).

Non-native herbaceous species The number of inflorescences of *Anthoxanthum odoratum* was not significantly different between treatments in 2001, although the proportional increase was much greater with mowing (Table 6). Burning significantly increased flowering of *Anthoxanthum odoratum* in 1997, but that response has not been repeated with subsequent treatments (Table 6). Rather, the general trend has been for mowing to promote *Anthoxanthum odoratum* flowering compared to other treatments and to also promote flowering each year compared to the previous year's mowing response (Table 6).

Hand-removal significantly increased flowering of *Holcus lanatus* compared to burning in 2001, but responses to all treatments were not significantly different from that in the control

(Table 6). Initially, after the first two treatment periods, mowing promoted flowering of *Holcus lanatus* compared to the control and other treatments, but after the last two treatment periods flowering was particularly high in hand-removal treatments (Table 6). In contrast, burning, after four treatment periods, has inhibited flowering of *Holcus lanatus* compared to mowing and hand-removal, and has often decreased flowering levels below those found in the controls (Table 6).

As a group, flowering of the non-native graminoid species showed no significant treatment differences in 2001 compared to the unmanipulated control (Table 6). The number of inflorescences with burning, however, was significantly less compared to mowing in 2001 (Table 6). The pattern after four treatment periods is for both hand-removal and mowing to promote number of inflorescences of non-native graminoids compared to the controls, significantly so in two of the four treatment periods (Table 6). Moreover, the number of inflorescences has generally increased with mowing after each treatment period. Burning has maintained levels of flowering of non-native graminoids as a group similar to those of the controls (Table 6).

No treatments promoted the cover of *Chrysanthemum leucanthemum*, a non-native forb, compared to the control in 2001 (Table 7). However, the data suggest that *Chrysanthemum leucanthemum* may be increasing in abundance at the site as it was found in the hand-removal treatment for the first time in 2001 (Table 7) and also found growing in the control for the first time in 1999. *Chrysanthemum leucanthemum* showed increases in the burn treatment in the last two treatment periods, 1999 and 2001 (Table 7), with cover in 1999 consisting mostly of seedlings.

As a group, cover of non-native forb species showed no significant treatment differences in 2001 compared to the control (Table 7), which is same pattern as previous treatment periods except for 1997, in which significant reductions in cover compared to the controls occurred after burning and hand-removal in 1997 (Table 7).

Total herbaceous cover Mowing significantly increased total herbaceous cover compared to the control and to the burn treatment in 2001 (Table 9). All treatments have caused a general trend of increases in total herbaceous cover compared to the control, with significant increases with mowing in 1995 and 1997 and with hand removal in 1999 (Table 9). The largest increases have been with mowing after each treatment period (Table 9). The total herbaceous cover measures all vascular species in a quadrat, and does not measure the total cover of the study species.

DISCUSSION

Effects of experimental manipulations

Patterns and mechanisms of woody species responses Prescribed burning and hand-removal of woody species consistently reduced the overall cover of woody species to very low levels. Mowing, in contrast, did not significantly reduce woody abundance even after repeated mowing over a six-year period. Because all the woody species in this study–*Amelanchier alnifolia, Crataegus douglasii, Crataegus monogyna, Rubus discolor*, *Rubus laciniatus*, *Rosa eglanteria, Rosa nutkana*, and *Fraxinus latifolia* – can resprout after the removal of their biomass (Tiermenstein 1989, Reed 1993, Pendergrass 1996, Clark and Wilson personal observation), and hence can potentially regain cover quickly, lasting reduction of cover of these woody species requires killing individual plants. In this study, differences among treatments in the reduction in woody cover closely followed mortality rates (Table 3). The lowest survival was in burned plots, which also had significant reductions in woody plant cover. Survival did not vary between mowed and control treatment. The strong reduction in woody cover with hand-removal coupled with only moderate mortality, probably occurred because clipping of stems close to the ground removed some basal vegetative buds and so reduced the capacity of clipped plants to resprout. Mowing left more basal stem intact and did not reduce woody cover as effectively as hand clipping.

Although fire has been demonstrated to be effective in reducing the invasion of woody species in xeric or mesic prairie environments (Daubenmire 1968, Vogl 1974, Kozlowski and Ahlgren 1974, Bragg and Hulbert 1976, Kucera 1981, Collins and Wallace 1990), few studies document the effects of fire on wetland vegetation (Kirby et al. 1988, Schmalzer and Hinkle 1992, Kirkman and Sharitz 1994, Kirkman 1995). The handful of studies investigating fire effects on Willamette Valley wetland prairie vegetation show inconsistent responses of woody species, in contrast to this long-term study in which response of woody species to fire has been consistent (Streatfeild 1995, Clark and Wilson 1998, Acker 1991, Pendergrass 1996). Variation in the capacity of woody species to resprout after fire in conjunction with variation in fire intensity can readily explain these inconsistencies. Moreover, the way woody response is measured (density, cover, height, and biomass) can also make it difficult to find general patterns.

Patterns and mechanisms of graminoids and forbs responses The responses of graminoids and forbs to the various management treatments over the six year study period was mixed, thus precluding the ability to make predictions of species responses to management treatments based on functional groups. However, consistent response patterns to management treatment by individual graminoid species have emerged from this multi-year study. Of the six graminoid species measured, burning promoted the number of inflorescences for three species (*Carex unilateralis*, *Carex densa*, and *Juncus tenuis*), but decreased flowering for two species (*Holcus lanatus* and *Deschampsia cespitosa*). Increases in flowering by graminoids and other monocotyledons after fire in grasslands have often been observed (Daubenmire 1968, Gill 1981, Whelan 1995). The reduction of woody biomass by fire was probably not the mechanism for the increase in flowering, because these species (*Carex unilateralis*, *Carex densa*, and *Juncus tenuis*) did not also increase in number of inflorescences after hand-removal, which also reduced woody biomass. Rather, other effects of fire, such as release of nutrients, are more likely responsible for the increase in flowering. Burning, although it can lead to competitive release with a decrease in woody species cover, might not have increased flowering in *Holcus lanatus* and *Deschampsia cespitosa* because of direct mortality of tillers (Grime and Lloyd 1973, Wilson and Clark 1997, but see Pendergrass 1996, Clark and Wilson 1998). Clump and tussock graminoids, like *D. cespitosa*, can grow readily after fire from protected meristematic tissues buried inside the clump (Holttum 1955, Whelan 1995). However, these tussocks also can accumulate the litter of senesced leaves, which can continue to burn after a fire passes, increasing temperatures and causing tiller mortality, thus inhibiting growth and reducing resources for flowering (Vogl 1974, Wright and Bailey 1982).

The failure of any treatment to promote the cover of *Deschampsia cespitosa* is consistent with the patterns found in other Willamette Valley wetland prairie studies. Burning decreased aboveground vegetative and reproductive biomass and inflorescence number of *Deschampsia cespitosa* at Finley National Wildlife Refuge (Clark and Wilson 1998) and at the same site *Deschampsia cespitosa* cover was reduced in more recently burned areas compared to previously burned areas (Streatfeild and Frenkel 1997). In west Eugene wetland prairies, *Deschampsia cespitosa* frequency increased immediately after burning, but cover declined significantly, suggesting a shift from predominately large plants to a greater number of smaller plants (Pendergrass 1996). Cover, however, returned to pre-burn abundance the following year

(Pendergrass 1996). A similar pattern was observed in Horkelia Prairie (west Eugene) where *Deschampsia cespitosa* cover decreased almost 50% the first year after burning and then increased to slightly more than in the controls two years after the burn (Wilson et al. 1995).

Mowing often promoted flowering of the graminoid species (*Juncus tenuis*, *Anthoxanthum odoratum*, *Holcus lanatus*). The mechanisms for this increased flowering probably varied between species. Mowing may have increased flowering for *Juncus tenuis* due to the removal of cut litter, because flowering was also promoted with burning but not hand-removal. In some grasslands, vegetation responses to light and moderate grazing or repeated mowing followed by removal of cut material are very similar to those responses following fire (review by Daubenmire 1968). In contrast, however, mowing may have promoted flowering of *Holcus lanatus* by reducing the height of the competitive woody plants (even though mowing did not reduce woody cover) and releasing the *Holcus lanatus* from competitive suppression from shading, because flowering of *Holcus lanatus* was also promoted by hand-removal of woody species.

Patterns of forb responses to repeated management treatments have generally been inconsistent for individual species and for groups of native and non-native species during the entire study period. For example, management treatments had little effect on the response of *Veronica scutellata* in both 1995 and 1999, but in 1997 all treatments increased cover relative to the control. The increase in cover of *Veronica scutellata* with fire in 1997 is similar to previous studies in which *Veronica scutellata* increased in establishment or frequency in burned wetland prairies (Pendergrass 1996), but contrasts with other studies that showed significant decreases in survival, reproduction, and cover (Streatfeild and Frenkel 1997, Clark and Wilson 1998). Response to management treatments may be modified by interactions with other environmental factors. Also fires differ in their characteristics from year to year, potentially altering vegetation responses.

Due to lag time in response to disturbance, patterns of vegetation responses to repeated treatments may take several years to develop (Wilson and Clark 2001). For example, *Sidalcea cusickii* spp. *purpurea* showed an increase in cover with treatments for the first time in seven years. Five years after the initiation of this study, two native forbs *Sisyrinchium idahoensis* and *Eriophyllum lanatum* appeared for the first time in the burn treatments and are still present and flowering. *Chrysanthemum leucanthemum* was found in the hand-removal treatment for the first time in 2001 and also found growing in the control for the first time in 1999, suggesting that the abundance of this weedy non-native species may be increasing.

Management Implications

Restoration and conservation efforts often lack experimental validation, particularly with the use of fire (Lugo 1993, Whelan 1995, Montalvo et al. 1997, Palmer et al. 1997, Pickett and Parker 1997, Michener 1997, Wilson and Lantz 2000). By setting up management treatments as experiments and incorporating replication and controls, valid conclusions can be made. Use of pre-manipulation data, as with this present investigation, allows the separation of significant treatment effects from confounding effects of other factors, such as previous existing vegetation and annual variation in weather.

Management strategies for restoration of Willamette Valley native prairies require reduction in the abundance of woody species, the reduction or prevention of an increase in abundance of non-native pest plant species, and the increase or at least the maintenance of native plant species' abundance (Table 9). Our study shows that both prescribed burning and hand-removal of woody species reduced the abundance of woody species, indicating that hand-removal maybe a viable alternative to prescribed burning (Table 9). The pattern established thus far indicates that woody cover reduction is maintained with two-year treatment intervals of burning and hand-removal even with large increases in woody cover in control plots. In contrast to the other two treatments, repeated mowing with removal of cut material after four treatment periods did not reduce the abundance of woody species, and thus would not be a viable alternative management option (Table 9).

Implicit in the choice of fire as a tool for managers of native prairies are the assumptions that native herbaceous species are fire-adapted, with prescribed burning promoting or maintaining their abundance, and that many non-native herbaceous species are not adapted to fire, with prescribed burning inhibiting or at least not promoting the population size of these species. The results of this investigation show that native herbaceous species as a group were either promoted or did not change in abundance and flowering after burning compared to the controls, supporting the first assumption (Table 9). One important exception was the trend for reduction of flowering by fire of the key native grass, *Deschampsia cespitosa*. The non-native herbaceous species as a group did not increase in cover or flowering after burning compared to the controls, also supporting assumptions (Table 9).

The alternative management options to burning, hand-removal, and mowing, were generally successful in meeting the management objectives for herbaceous species (Table 9), with the exception for both alternatives of an unwanted increase in the flowering of non-native graminoid species.

In summary, the results to date show that burning of woody species is the best option of the three tested management treatments for achieving the restoration goals for native wetland prairies (Table 9). Because of the ineffectiveness of mowing with removal of cut material in decreasing cover of woody species combined with the tendency to promote flowering of non-native graminoid species, this treatment should be avoided.

Long-term patterns of vegetation response to repeated treatments may not be apparent for several years as this study demonstrates. However, although some patterns, such as flowering response by long-lived perennial graminoids, are emerging, changes in the number of inflorescences after treatment may take considerable time to influence long-term population dynamics. The importance of seedling recruitment to the population dynamics of native species is unknown in this ecosystem. Fires differ in their characteristics from year to year; only repeated treatments and continued monitoring will conclusively demonstrate the effectiveness of these management approaches.

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Figure 1. Map of vegetation types at the BLM Danebo wetland office site (compiled by Glenn Miller, Oregon Department of Agriculture and provided by the BLM Coast Range Office)

Figure 2. Map of the Danebo study site showing the 5 blocks (not drawn to scale) and the location of treatments within the blocks: *M* is mow with litter removal, *H* is hand-removal of woody species, *C* is no manipulation and *B* is burn.

Table 1. A list of vascular plants found at the Danebo wetland prairie site. All species are in the Willamette Valley wet prairie community unless otherwise indicated. The species list was compiled by Peter Zika, September 1988, and provided by the BLM Coast Range Office. *Alien, established in the Oregon flora after white settlement; **[1]**Upland disturbed soils; **[2]**Planted; **[3]**Sensitive Species

Acer macrophyllum[1]
Acer saccharinum*[2]
Agrostis capillaris*[1]
Agrostis stolonifera
Aira caryophyllea*[1]
Allium amplectens
Allium vineale*
Alopecurus geniculatus
Alopecurus pratensis*[1]
Amelanchier alnifolia
Anthemis cotula*[1]
Anthoxanthum odoratum*[1]
Araliaceae sp.*[1,2]
Arrenatherum elatius*[1]
Aster hallii
Avena barbata*[1]
Barbarea orthoceras
Beckmannia syzigachne
Bellis perennis*1
Berberis sp.*[1,2]
Betula pendula*
Bidens frondosa
Boisduvalia densiflora
Brassica hirta*
Briza minor*
Brodiaea hyacinthina
Bromus carinatus
Bromus mollis*[1]
Camassia quamash
Cardamine oligosperma
Carex densa
Carex echinata
Carex feta
Carex leporina
Carex sp. (ovales)
Carex unilateralis
Centaureum umbellatum*
Cerastium viscosum*
Chrysanthemum leucanthemum*[1]
Chrysanthemum parthenium*[1]
Cirsium arvense*[1]
Cirsium vulgare*[1]
Convolvulus arvensis*[1]
Crataegus douglasii
Crataegus monogyna*[1]
Cynosurus echinatus*
Dactylis glomerata*[1]
Danthonia californica
Daucus carota*[1]
Deschampsia cespitosa
Digitalis purpurea*[1]
Dipsacus sylvestris*[1]
Downingia yina
Eleocharis acicularis
Eleocharis palustris
Epilobium glandulosum
Epilobium paniculatum
Epilobium watsonii
Eriophyllum lanatum
Eryngium petiolatum
Eschscholzia californica[1]
Festuca arundinacea*
Festuca bromoides*
Festuca megalura*[1]
Fraxinus latifolia
Galium aparine
Galium parisiense*
Geranium dissectum*
Gnaphalium palustre
Grindelia squarossa
Hedera helix*[1,2]
Holcus lanatus*
Hordeum brachyantherum
Hordeum murinum*[1]
Hypericum perforatum*
Hypocharis radicata*
Ilex aquifolium*[1,2]
Iris sp.*[2]
Juncus bufonius
Juncus effusus
Juncus ensifolius
Juncus nevadensis
Juncus oxymeris
Juncus patens
Juncus tenuis
Lactuca serriola*[1]
Lapsana communis*[1]
Lathyrus latifolius*[1]
Lathyrus sphaericus*
Leontodon nudicaulis*
Liliaceae sp.*[2]
Lolium perenne*[1]
Lotus corniculatus*[1]
Lotus formosissimus
Lotus purshianus
Lysimachia nummularia*
Madia glomerata
Madia sativa
Malva neglecta*[1]
Mentha pulegium*
Microcala quadrangularis[3]
Microseris laciniata
Microsteris gracilis
Moenchia erecta*
Montia fontana
Montia linearis
Myosotis discolor*
Narcissus pseudo-narcissus*
Oemleria cerasiformis
Parentucellia viscosa*[1]
Phalaris aquatica*
Phalaris arundinacea
Phleum pratense*
Picea pungens*[1,2]
Pinus sp.*[1,2]
Plagiobothrys figuratus
Plagiobothrys scouleri
Plantago lanceolata*[1]
Poa annua*[1]
Poa compressa*[1]
Poa pratensis*
Poaceae spp.
Polygonum aviculare*[1]
Polygonum douglasii
Populus nigra*[1,2]
Populus trichocarpa
Potentilla sp.
Prunella vulgaris*
Prunus avium*[1]
Prunus domestica[1,2]
Pseudotsuga mensiesii[1,2]
Pyrus communis*[1]
Pyrus fusca
Pyrus malus*[1,2]
Ranunculus aquatilis
Ranunculus occidentalis
Ranunculus orthorhynchus
Rhus diversiloba
Rosa eglanteria*[1]
Rosa nutkana
Rosa sp.
Rosa multiflora*[1]
Rubus discolor*[1]
Rubus laciniatus*[1]
Rubus leucodermis[1]
Rumex acetosella*
Rumex crispus*
Rumex sp.
Salix lasiandra
Salix piperi
Salix piperi x sitchensis
Salix scouleriana
Salix sitchensis
Scilla sp.*[2]
Sanguisorba minor*[1]
Senecio vulgaris*
Senecio jacobea*[1]
Scirpus acutus
Sidalcea cusickii ssp. purpurea[3]
Sisyrinchium idahoensis
Spergularia rubra*[1]
Syringia vulgaris*[1,2]
Taraxacum officinale*
Thuja plicata[1,2]
Trifolium dubium*
Typha latifolia
Veronica arvensis*
Veronica scutellata
Vicia cracca*[1]
Vicia hirsute*[1]
Vicia sativa*[1]
Vicia tetrasperma*

Table 2. Average cover (%) of woody species and average cover (%) or number of inflorescences of common herbaceous plants in 1994 before management treatments. Woody species include shrubs *Rubus discolor*, *Rubus laciniatus*, *Rosa nutkana, Rosa eglanteria, Crataegus douglasii, Crataegus monogyna*, *Amelanchier alnifolia* and the tree *Fraxinus latifolia*. Values within parentheses are standard deviations.

	Before Treatments			
	Burn	Hand-removal	Mow	Control
Woody species (cover)	10.5 (7.7)	21.3 (21.0)	7.1 (4.6)	12.9 (6.0)
Common native graminoid species				
Cover				
Deschampsia cespitosa	18.0 (6.5)	18.7 (4.4)	21.5 (3.9)	15.3 (4.0)
Number of inflorescences				
Carex unilateralis	0.0 (0.0)	2.1 (4.1)	1.0 (2.2)	0.3 (0.4)
Carex densa	1.4 (2.1)	0.2 (0.4)	0.7 (1.1)	1.2 (1.2)
Carex feta/leporina	0.3 (0.4)	0.4 (0.9)	1.7 (2.2)	0.3 (0.3)
Carex sp.	1.4 (1.8)	0.4 (0.9)	0.9 (1.5)	1.6 (0.6)
Deschampsia cespitosa	6.3 (4.3)	6.7 (2.7)	7.9 (5.4)	4.7 (2.3)
Juncus tenuis	1.3 (0.7)	0.9 (0.8)	1.1 (0.6)	3.1 (2.3)
Group total	10.6 (5.3)	10.7 (5.6)	13.3 (5.5)	11.1 (4.5)
Common native forb species				
Cover				
Eriophyllum lanatum	0.0 (0.0)	0.9 (1.6)	0.0 (0.0)	0.5 (1.0)
Lotus purshiana	1.5 (1.2)	1.2 (1.4)	1.7 (1.6)	2.2 (2.0)
Sidalcea cusickii ssp. *purpurea*	0.0 (0.0)	0.0 (0.0)	0.1 (0.2)	0.0 (0.0)
Veronica scutellata	0.8 (1.2)	0.8 (1.1)	0.6 (1.0)	1.3 (2.1)
Group total	2.3 (1.2)	2.9 (1.8)	2.4 (1.4)	4.0 (3.0)
Number of inflorescences				
Sisyrinchium idahoensis	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Common non-native graminoid species				
Number of inflorescences				
Anthoxanthum odoratum	0.9 (1.3)	2.4 (5.4)	4.0 (7.4)	10.7 (23.7)
Holcus lanatus	5.8 (3.7)	2.7 (2.5)	2.9 (3.5)	3.6 (2.1)

Group total	6.7 (4.6)	5.1 (4.3)	6.9 (6.2)	14.3 (23.0)
Common non-native forb species				
Cover				
Centaurium umbellatum	0.5 (0.6)	0.1 (0.2)	0.5 (0.7)	0.8 (0.9)
Chrysanthemum leucanthemum	0.3 (0.6)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Hypericum perforatum	1.4 (1.2)	1.7 (1.5)	0.7 (1.0)	1.1 (0.5)
Lysimachia nummularia	0.0 (0.0)	2.7 (6.0)	0.0 (0.0)	3.4 (7.6)
Vicia sativa	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.3 (0.3)
Vicia tetrasperma	1.6 (1.0)	1.1 (1.7)	1.1 (1.0)	1.2 (0.7)
Group total	2.2 (1.0)	4.5 (5.6)	1.2 (1.6)	5.3 (7.2)
Overall cover (all species)	39.1 (6.3)	35.1 (5.5)	36.2 (4.3)	38.4 (8.6)

Table 3. Average percent survival and average proportional change in cover for woody species between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 2001 within treatment areas. Reported values are untransformed means. Positive values of cover show increases in abundances after the manipulation; negative values show declines. *P* are the probabilities that survival and proportional changes differed significantly among treatments just by chance (ANOVA, rank transformation). Treatment means with the same letters were statistically indistinguishable.

		Treatment				
		Burn	Hand removal	Mow	Control	*P*
Survival	1995	33.3b	60.0ab	88.3a	83.3a	**0.03**
Cover	1994-1995	-0.91c	-0.82bc	-0.44ab	-0.32a	**0.02**
	1994-1997	-0.63b	-0.79b	0.25a	0.20a	**0.00**
	1994-1999	-0.81b	-0.65b	0.56a	1.44a	**0.00**
	1994-2001	-0.74c	-0.54bc	0.37ab	1.03a	**0.00**

Table 4. Average proportional change in cover and number of inflorescences of common native graminoid species within treatment areas between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 2001. Reported values are untransformed means. Positive values show increases in abundances after the manipulation; negative values show declines. *P* is the probability that the proportional changes differed significantly just by chance (ANOVA). Treatments sharing letters were statistically indistinguishable.

Common native graminoids		Treatment				
		Burn	Hand-removal	Mow	Control	*P*
Cover						
Deschampsia cespitosa	1995	0.25	-0.14	-0.25	-0.11	0.50
	1997	0.31	0.08	-0.01	0.31	0.77
	1999	0.42	0.21	0.07	-0.06	0.92
	2001	-0.24	0.10	-0.20	0.20	0.35
Number of inflorescences						
Carex unilateralis	1995	0.00	0.45	-0.08	0.47	0.56
	1997	0.00	0.66	0.36	0.27	0.99
	1999	1.80	-0.40	0.00	0.00	0.43
	2001	4.00b	-0.40a	0.01ab	1.21b	**0.05**
Carex densa	1995	0.74	-0.20	0.58	-0.50	0.61
	1997	7.00	-0.20	0.58	-0.42	0.28
	1999	1.22	-0.20	0.40	-0.56	0.23
	2001	3.21	-0.20	0.03	-0.31	0.51
Carex leporina/feta	1995	-0.40	-0.20	-0.80	-0.60	0.17
	1997	-0.40	-0.20	-0.63	2.10	0.35
	1999	-0.40	-0.20	-0.80	-0.60	0.17
	2001	-0.40	-0.20	-0.80	-0.60	0.17
Carex sp.	1995	4.98	12.87	9.77	1.34	0.63
	1997	21.52	3.73	27.37	2.10	0.61
	1999	1.23	19.2	13.02	2.03	0.56
	2001	0.38	12.53	17.17	1.53	0.25
Deschampsia cespitosa	1995	1.92	2.21	1.01	2.46	0.21
	1997	0.99b	2.35a	2.16ab	3.12a	**0.10**
	1999	0.01b	1.74a	1.07ab	0.65ab	**0.08**
	2001	0.21	0.79	-0.19	1.39	0.32
Juncus tenuis	1995	43.74	20.12	16.25	5.73	0.35
	1997	4.74a	1.93ab	6.08a	0.93b	**0.02**
	1999	13.14	2.57	12.38	2.60	0.26
	2001	18.27b	6.36ab	14.57b	2.86a	**0.02**
Group total	1995	6.29	2.62	2.08	2.71	0.58
	1997	2.02	1.97	2.60	1.48	0.51
	1999	1.73	1.41	1.47	0.76	0.18
	2001	3.49	0.90	1.05	0.63	0.92

Table 5. Average proportional change in cover and number of inflorescences of common native forb species within treatment areas between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 2001. Reported values are untransformed means. Positive values show increases in abundances after the manipulation; negative values show declines. *P* is the probability that the proportional changes differed significantly just by chance (ANOVA). No comparisons were made in years when a species was found by chance in only one treatment. Treatments sharing letters were statistically indistinguishable.

Common native forbs		Treatment				
		Burn	Hand-removal	Mow	Control	*P*
<u>Cover</u>						
Eriophyllum lanatum	1995	0.00	0.12	0.00	-0.16	0.36
	1997	0.00	0.47	0.00	-0.10	0.13
	1999	0.47	0.55	0.00	0.35	0.89
	2001	1.67	0.83	0.00	0.55	0.90
Lotus purshiana	1995	-0.47	0.34	-0.43	-0.44	0.30
	1997	-0.04a	14.83a	-0.52ab	-0.64b	**0.09**
	1999	-0.15	3.88	-0.16	-0.41	0.77
	2001	0.76	-0.34	-0.35	-0.41	0.73
Sidalcea cusickii ssp. *purpurea*	1995	0.00	0.00	-0.30	0.00	
	1997	0.00	0.00	-0.10	0.00	
	1999	0.00	0.00	0.00	0.00	
	2001	0.00	0.00	0.11	0.00	
Veronica scutellata	1995	-0.23	-0.24	-0.29	-0.39	0.89
	1997	0.21ab	0.79a	0.98a	-0.54b	**0.08**
	1999	-0.13	0.00	-0.26	-0.36	0.81
	2001	-0.39	-0.03	0.26	0.46	0.57
Group total	1995	-0.41	-0.22	-0.57	-0.56	0.35
	1997	0.08a	1.67a	-0.14ab	-0.77b	**0.04**
	1999	-0.25	0.04	-0.25	-0.56	0.13
	2001	-0.17	-0.22	-0.06	-0.57	0.91
<u>Number of inflorescences</u>						
Sisyrinchium idahoensis	1995	0.00	0.00	0.00	0.00	
	1997	0.00	0.00	2.47	0.00	
	1999	6.27	0.00	4.27	0.00	0.11
	2001	10.67	0.00	0.67	0.00	0.43

Table 6. Average proportional change in number of inflorescences of common non-native graminoids species within treatment areas between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 200. Reported values are untransformed means. Positive values show increases in abundances after the manipulation; negative values show declines. *P* is the probability that the proportional changes differed significantly just by chance (ANOVA). Treatments sharing letters were statistically indistinguishable.

Common non-native graminoids		Treatment				
		Burn	Hand-removal	Mow	Control	*P*
Number of inflorescences)						
Anthoxanthum odoratum	1995	1.04	2.66	0.64	-0.27	0.45
	1997	4.67ab	0.44bc	4.80a	-0.25c	**0.02**
	1999	1.39	0.80	13.39	3.22	0.33
	2001	7.90	2.2	73.92	45.72	0.11
Holcus lanatus	1995	-0.71	1.34	4.45	-0.38	0.45
	1997	-0.72b	5.46a	11.50a	-0.80b	**0.01**
	1999	-0.90b	6.98a	1.21a	-0.19a	**0.02**
	2001	-0.92a	8.17b	0.09ab	-0.02ab	**0.06**
Group total	1995	-0.54	-0.21	0.19	-0.52	0.68
	1997	0.45cb	2.79a	1.92ab	-0.68c	**0.03**
	1999	-0.55b	0.59ab	1.47a	-0.18b	**0.01**
	2001	0.16a	1.90ab	3.35b	1.55ab	**0.07**

Table 7. Average proportional change in cover of common non-native forb species within treatment areas between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 2001. Reported values are untransformed means. Positive values show increases in abundances after the manipulation; negative values show declines. No comparisons were made in years when a species was found by chance in only one treatment. *P* is the probability that the proportional changes differed significantly just by chance (ANOVA). Treatments sharing letters were statistically indistinguishable.

Common non-native forbs (cover)		Treatment				
		Burn	Hand-removal	Mow	Control	*P*
Centaurium umbellatum	1995	-0.40	-0.27	-0.37	-0.77	0.64
	1997	0.22	1.97	2.01	3.41	0.42
	1999	-0.40	-0.05	-0.46	-0.63	0.62
	2001	-0.40	-0.13	-0.27	2.56	0.76
Chrysanthemum leucanthemum	1995	-0.35	0.00	0.00	0.00	
	1997	-0.28	0.00	0.00	0.00	
	1999	0.03	0.00	0.00	1.13	0.92
	2001	0.56	2.50	0.00	1.17	0.29
Hypericum perforatum	1995	-0.99	-0.89	-0.08	-0.60	0.25
	1997	-0.89b	-0.78b	-0.24a	0.92a	**0.00**
	1999	-1.00	-0.94	-0.47	-0.88	0.19
	2001	-0.82	-0.89	0.23	-0.59	0.49
Lysimachia nummularia	1995	0.00	-0.14	0.00	-0.11	0.42
	1997	0.00	-0.10	0.00	-0.06	0.42
	1999	0.00	-0.13	0.00	-0.14	0.43
	2001	0.00	-0.07	0.00	-0.12	0.43
Vicia sativa	1995	0.00a	0.07a	0.13a	-0.60b	**0.03**
	1997	4.80	0.03	1.30	-0.20	0.45
	1999	0.00	4.83	7.13	-0.05	0.30
	2001	0.00	-0.15	2.33	0.10	0.32
Vicia tetrasperma	1995	-0.65ab	-0.30a	-0.15a	-0.91b	**0.07**
	1997	-0.03	1.52	0.39	0.35	0.68
	1999	-0.04	3.15	3.91	1.19	0.37
	2001	0.16	2.65	1.18	0.34	0.24
Group total	1995	-0.89	-0.78	-0.48	-0.77	0.24
	1997	-0.30b	-0.45b	0.43a	0.28a	**0.03**
	1999	-0.44b	-0.11ab	2.32a	-0.15ab	**0.08**
	2001	-0.50	-0.54	-0.20	-0.42	0.25

Table 8. Average proportional change total cover of all vascular species within treatment areas between 1994 and 1995, between 1994 and 1997, between 1994 and 1999, and between 1994 and 2001. Reported values are untransformed means. Positive values show increases in abundances after the manipulation; negative values show declines. *P* is the probability that the proportional changes differed significantly just by chance (ANOVA). Treatments sharing letters were statistically indistinguishable.

Total herbaceous cover	Treatment				
	Burn	Hand-removal	Mow	Control	*P*
1995	0.01b	0.04b	0.32a	-0.12b	**0.01**
1997	0.41	0.42	0.60	0.31	0.71
1999	0.33ab	0.42a	0.72a	-0.09b	**0.04**
2001	0.19b	0.20ab	0.49a	0.10b	**0.09**

Table 9. Summary of the effectiveness of three management treatments (prescribed burning, hand-removal of woody species, and mowing with removal of cut material) in fulfilling management objectives for native wetland prairies in the Willamette Valley based on responses of species groups after four treatment periods from 1994 to 2001. "Yes" indicates restoration objective achieved and "No" indicates restoration objective not met.

Restoration Objective	Treatments		
	Burning	Hand-removal of woody species	Mowing with removal of cut material
Reduce abundance of woody species	YES (decreased)	YES (decreased)	NO (no significant change)
Reduce or not promote abundance of non-native herbaceous species:			
- Graminoid inflorescences	YES (no significant change)	NO (trend was to promote)	NO (trend was to promote)
- Forb cover	YES (reduced or no significant change)	YES (reduced or no significant change)	YES (generally no significant change)
Promote or maintain abundance of native herbaceous species:			
- Graminoid cover	YES (no significant change)	YES (no significant change)	YES (no significant change)
- Graminoid inflorescences	YES (no significant change)*	YES (no significant change)	YES (no significant change)
- Forb cover	YES (promote or no significant change)	YES (promote or no significant change)	YES (no significant change)

* with exception of sometimes reduction in the number of inflorescences for *Deschampsia cespitosa*