# Controlling exotic grasses while maintaining native plant communities in fire-maintained wet prairies

2018

## Progress Report to the US Army Corps of Engineers, Willamette Valley Projects

Report prepared by A. Lisa Schomaker, Matt A. Bahm and Erin C. Gray

*Institute for Applied Ecology*

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.

Questions regarding this report or IAE should be directed to:

Matt A. Bahm

Conservation Research Program Director

Institute for Applied Ecology

563 SW Jefferson Avenue

Corvallis, Oregon 97333

phone: 541-753-3099

email: mattab@appliedeco.org

## ACKNOWLEDGEMENTS

The authors gratefully acknowledges the cooperation in 2018 provided by the USACE, particularly Wes Messinger with Willamette Valley Projects, and IAE staff Michelle Allen and Denise Giles.

**Cover photograph**: Pre-treatment monitoring of experimental plots at Rose Prairie, June 2010.

**Suggested Citation**

Schomaker, A.L., M.A. Bahm, and E.C. Gray. 2018. Controlling exotic grasses while maintaining native plant communities in fire-maintained wet prairies; Progress Report. Prepared by Institute for Applied Ecology for U.S. Army Corps of Engineers, Willamette Valley Projects. Corvallis, Oregon. vii + 32 pp.

# TABLE OF CONTENTS

## LIST OF FIGURES

# EXECUTIVE SUMMARY

The treatments tested in this study show potential for addressing a subset of restoration goals within the Fern Ridge RNA (reducing *Anthoxanthum odoratum* cover, increasing native species cover, and decreasing exotic species cover). Currently, no individual treatment provides desired results in all of the measured variables but a combination of the strategies tested here may prove effective.

## Rose Prairie

In 2018, cover of *Anthoxanthum odoratum* ranged from 7% to 31%, with variation among treatments. The burn + glyphosate (Feb 2015) treatment had the highest mean *Anthoxanthum* cover among the treatments, including the control. Native species cover ranged from 25% to 44% and exotic cover from 15% to 44%; neither group differed significantly between treatments.

Native graminoid cover ranged from 15% to 38%, with significantly higher cover in control plots. Exotic graminoid cover (composed entirely of *A. odoratum*) ranged from 7% to 31%, and was highest in the burn + glyphosate (Feb 2015) treatment.

Native forb cover ranged from 2% to 13%, with the burn + 1 application of glyphosate, burn + 2 applications of glyphosate, and burn + 1 application of fusilade treatments having the highest cover of native forbs, while the control and burn + glyphosate (Feb 2015) treatment had significantly lower native forb cover. Exotic forb cover ranged from 9% to 18%, and did not vary among treatments.

## Fisher Butte

In 2018, cover of *Anthoxanthum odoratum* ranged from 8% to 15%, and did not vary among treatments. Native species cover ranged from 13% to 32%, with significantly higher cover in the control plots. Exotic species cover ranged from 33% to 45%, with no significant differences between treatments.

Native graminoid cover ranged from 4% to 25%, with significantly higher cover in the control plots. Exotic graminoid cover ranged from 8% to 16%, with no significant differences between treatments.

Native forb cover ranged from 5% to 13%, with the burn + 1 application of glyphosate and burn + 2 applications of fusilade having significantly higher native forb cover than the control and burn + glyphosate (Feb 2015) treatment. Exotic forb cover ranged from 18% to 35%, and did not differ significantly between treatments.

Over the course of this study, plant community responses to management treatments were variable and hard to differentiate from responses to unmeasured abiotic factors such as extreme hydrologic events or biotic factors such as annual population fluctuations (especially in our target species *A. odoratum*). The treatments we tested in our experiments can't be recommended to remove *A. odoratum*. Further testing of treatments that incorporate biotic conditions at the individual sites to more specifically target *A. odoratum* are needed to aid in management of these wet prairie sites.

# Controlling exotic grasses while maintaining native plant communities in fire-maintained wet prairies

**PROGRESS REPORT TO THE US ARMY CORPS OF ENGINEERS, WILLAMETTE VALLEY PROJECTS**

## INTRODUCTION

Wetland 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). The Fern Ridge Research Natural Area (RNA) contains substantial remnant wetland prairies, and is dedicated to serve as a research site and reference community for the Willamette Valley wet prairie system. It consists of three main units; Rose Prairie, Royal Amazon, and Fisher Butte, all of which support rare and endangered plant species. One of these species is the endangered *Lomatium bradshawii* (Bradshaw's lomatium, Figure 1). *Lomatium bradshawii* occurs at ~60 sites in the Willamette Valley and Clark County, Washington, and most populations are small (10-1,000 plants) (U.S. Fish and Wildlife Service 2010). *Lomatium bradshawii* is found in wet prairie habitats, and protected, good quality wet prairie remnants like the Fern Ridge RNA are critical for the recovery of this species.

**FIGURE 1. THE ENDANGERED *LOMATIUM BRADSHAWII* (BRADSHAW'S LOMATIUM), FOUND IN THE FERN RIDGE RESEARCH NATURAL AREA IN THE WILLAMETTE VALLEY.**

Wet prairie habitats at Fern Ridge RNA are currently managed using prescribed fire, which benefits the plant community by decreasing thatch and promoting germination by native species. Unfortunately, it has also been observed that the exotic grass *Anthoxanthum odoratum* (sweet vernal grass) can increase under a burning regime.

This species is beyond acceptable levels in some parts of the RNA, particularly Rose Prairie. Other exotic grasses, such as *Agrostis* spp., *Holcus lanatus*, and *Schedonorus phoenix* can also be invasive in wet prairies. For example, *Agrostis* has invaded the tops of mima mounds at Rose Prairie and Royal Amazon and the upper portion of Fisher Butte. These exotic grasses are a significant threat to *L. bradshawii* and other prairie species.

There is a need for alternative management strategies to reduce the abundance of exotic grasses, particularly *A. odoratum*, without causing harm to native plants. Management strategies must be carefully crafted and tested to avoid harm to rare and endangered plant species. Because of the wetland status of these sites, use of herbicides is constrained to chemicals appropriate for use in wetlands.

The ultimate goals of this project are to improve the diversity (both evenness and richness) of native species and decrease the cover of exotic species. We will compare various methods of control for these grasses in the presence of an unpredictable fire regime. This project has three main tasks:

1. Determine appropriate treatment alternatives and experimental design for testing treatments.
2. Monitor experimental plots and analyze data.
3. Communicate results to partners and the scientific community.

Here we report on our progress on these tasks, and summarize the treatment data collected at Rose Prairie and Fisher Butte.

## Treatment Alternatives

IAE staff reviewed published and unpublished literature and consulted with local experts and Corps specialists to develop a background on the current best practices for wet prairie restoration in the Willamette Valley and identify knowledge gaps. The treatments recommended for this project are 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 *pers. comm.*) in Wetland Restoration Enhancement Program sites (M. Blakeley-Smith *pers. comm.*) and upland prairies in the Willamette Valley and Puget Trough (Boyer 2008; Stanley et al. 2008, 2010). IAE staff used this background information to develop treatment alternatives. Each alternative and its rationale are described below:

1. Control (fire only): because Fern Ridge RNA is typically managed by burning, fire represents the 'control' condition to which we wish to compare the treatment alternatives.

2. Burn + glyphosate (1 week after): A broad spectrum herbicide applied soon after fire can target rapidly re-sprouting exotic species (Stanley et al. 2010). Many native species are much slower to green up after fire, so this broad-spectrum herbicide can actually be selective in its effects.

3. Burn + glyphosate 2x (1 week after) + glyphosate (Feb.): As above, with an additional glyphosate treatment in late winter, before natives have emerged but exotic grasses are active.

4. Burn + fusilade (1 week after): similar to treatment 2, but with a grass-specific herbicide, to insure there is no damage to native forbs.

5. Burn + fusilade 2x (1 week after) + fusilade (Feb.): similar to treatment 4, but with an additional application in late winter to target exotic grasses.

6. Burn + surfactant (NuFilm) only: a control for any impacts of the surfactant.

7. Burn + glyphosate (February 2015): Glyphosate was inadvertently applied to Fire + surfactant only plots in 2015 and we included the novel treatment in analysis.

Treatments at Rose Prairie were initiated in 2011 and at Fisher Butte in 2014. Treatments were applied once at Fisher Butte. We used an adaptive management framework and applied Fusilade to treatment 4 (above) and Glyphosate (was intended for treatment 3, but was inadvertently applied to treatment 6) at Rose Prairie in 2015 (Appendix A. Rose Prairie map, plot locations, and treatment assignments). Each year, IAE staff consulted with Corps specialists to decide if additional treatments were necessary.

## Experimental design and data collection

### Rose Prairie

In 2010, five blocks were established at Rose Prairie (Figure 2, Appendix A). Blocks were haphazardly distributed in pool habitat throughout the site. Each block consisted of six 5 x 5m$^2$ plots, separated by 1m wide buffers. Block corners were marked with rebar extending approximately 20cm above the soil surface. After the prescribed burn, plots were marked with 1.5m tall fiberglass posts marked with colored flagging. Treatments were randomly assigned to plots within each block (Appendix A).

In early June 2010 and 2012, we surveyed percent cover of all vascular plant species within a 1m$^2$ sampling quadrat haphazardly placed in the center of each plot. We also assessed cover of bare soil, litter, and moss. Percent cover was visually estimated to the nearest 1%; for species occurring at <1% cover we estimated cover to 0.1% or 0.5%. In 2015, we added a second 1m$^2$ sampling quadrat in the central portion of the plot to better represent the entire treated area. Species names and supplementary information follows the USDA Plants Database (http://plants.usda.gov/) and local floras.

Rose Prairie was burned October 24, 2011 (Figure 3). Post-fire germination occurred later than expected, thus herbicide treatments were applied November 10, 2011 (approximately 3 weeks post fire). All treatments used NuFilm as the surfactant, as it is recommended for use in areas occupied by arthropods. The second application of herbicides for treatment 3 (glyphosate) occurred in February 2012. Fusilade could not be applied in February 2012 as planned due to standing water at the site. Thus, treatments 4 and 5 were functionally the same (burn + 1 fusilade treatment) and were combined for analysis in previous years. However, a follow-up application of fusilade was applied to treatment 4 in February 2015 ("Fus + Fus Feb 2015"). An application of glyphosate intended for treatment 3 was inadvertently applied to treatment 6 (burn + surfactant only) in February 2015. The novel treatment was included in the analysis, while the single treatment, plot 6 (not sprayed due to standing water) was eliminated. Post-treatment vegetation monitoring was conducted in late May/early June of 2012 and 2015-2018.

### Fisher Butte

In 2011, five blocks were established at Fisher Butte (Appendix B). Treatments were randomly assigned to plots within each block (). Block corners were marked with rebar extending approximately 20 cm above the soil surface. Plot corners within blocks were temporarily marked using spikes. Plots were permanently marked after the controlled burn with color-coded fiberglass posts. Treatments were randomly assigned to plots within each block. In early June 2011, plot monitoring occurred as described above for Rose Prairie.

In 2014, we resampled the vegetation at Fisher Butte in order to have up-to-date pre-treatment conditions (Figure 4). Based on our results from Rose Prairie in 2012, at Fisher Butte we added more sampling quadrats within each treatment plot to obtain a more representative sample of the treatment units. We sampled three, 1 $m^2$ quadrats per treatment plot. Each 1$m^2$ sampling quadrat was haphazardly placed within each treatment plot. In late May/early June of each year, we assessed percent cover of all vascular plant species and cover of bare soil, litter, and moss in each of the 1$m^2$ sampling quadrats. Percentage cover is visually estimated to the nearest 1%; for species occurring at <1% cover we estimated cover to 0.1% or 0.5%.

Fisher Butte was burned October 9, 2014. All initial treatments were applied in 2014 and used NuFilm as the surfactant, as it is recommended for use in areas occupied by arthropods. The second application of herbicides for treatment 3 (glyphosate) in February 2015 was inadvertently applied to treatment 6 (surfactant only) plots, and represents a unique unplanned treatment. Thus, treatments 2 and 3 were functionally the same (burn + one glyphosate treatment) and combined for analysis. Post-treatment vegetation monitoring was conducted in late May 2015, 2016, 2017, and 2018.

## Statistical Analysis

Analysis of Variance (ANOVA) procedures were conducted in R (R Core Team 2017) to determine the effect of each treatment on *Anthoxanthum odoratum* cover, total cover of native and exotic species, native and exotic graminoid cover, native and exotic forb cover, bare ground, and litter cover. We tested for effects of site on treatment and when significant effects were found, individual ANOVAs were conducted for each site. We used Fisher's LSD multiple comparisons test to evaluate the differences among treatment means.

**FIGURE 2. Rose Prairie, June 2010, prior to prescribed burn and management treatments.**

**FIGURE 3. Rose Prairie, October 2011, after the prescribed burn, prior to herbicide treatments.**

**FIGURE 4. Fisher Butte in June 2014, prior to prescribed burn and management treatments.**

# RESULTS

## Rose Prairie

In pre-treatment monitoring at Rose Prairie, we found 42 vascular plant species (Appendix C); post-treatment monitoring produced 43 species in 2012 (Bois 2012), 40 species in 2015, 42 species in 2016, 32 species in 2017, and 34 species in 2018 (Appendix D). In 2018 there was a significant difference in species richness between treatments (p=0.018). The burn + fusilade 2x treatment had the highest species richness, while the burn + glyphosate (Feb 2015) had the lowest.

### *Anthoxanthum odoratum*

*Anthoxanthum odoratum* cover ranged from 7% to 31%, with variation among treatments (p=0.021; Figure 5). The burn + glyphosate (Feb 2015) treatment had the highest *Anthoxanthum* cover at about three times the cover observed in control plots.

### Nativity

Native species cover did not vary significantly between treatments in 2018 (p=0.237) and ranged from 25% to 44% (Figure 6). Total exotic cover ranged from 15% to 44%, with no significant variation among treatments (p=0.059; Figure 6).

### Graminoid Cover

Native graminoid cover ranged from 15% to 38%, with significantly higher native cover in control plots than other treatment plots, excluding the burn + fusilade 2x treatment (p=0.025; Figure 7). Among the treated plots, there was no significant difference in native graminoid cover. Exotic graminoid cover ranged from 7% to 31%, with significant variation among treatments (p=0.021; Figure 7). The burn + glyphosate (Feb 2015) treatment had the highest exotic graminoid cover (represented primarily by *A. odoratum*).

### Forb Cover

Native forb cover ranged from 2% to 13%, and varied significantly among treatments (p=0.001). The burn + 1 application of glyphosate and burn + glyphosate x2 treatments had the highest cover of native forbs, while the burn + fusilade x2, burn + glyphosate (Feb 2015) and control treatments had significantly lower native forb cover (Figure 8). Mean exotic forb cover ranged from 9% to 18%, and did not vary among treatments (p=0.523, Figure 8).

### Substrate

Cover of bare ground substrate ranged from 5% to 30%, with control plots having the lowest cover of bare ground (p=0.045; Figure 9). Litter cover ranged from 6% to 32%, with significantly higher litter cover in control plots than in any other treatment plots (p<0.001; Figure 9).

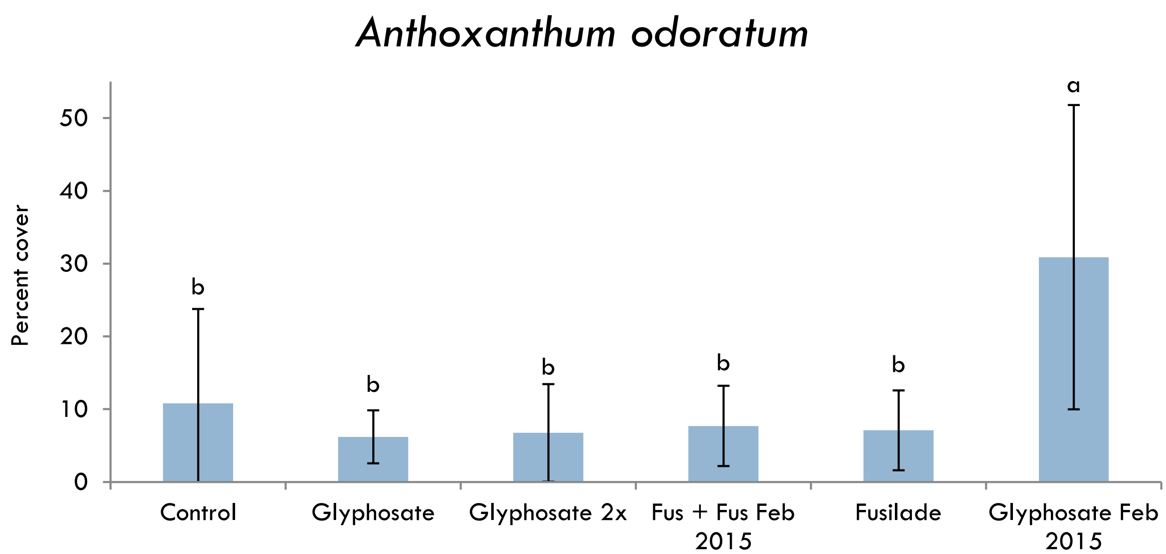



**FIGURE 5. *ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. LOWERCASE LETTERS ABOVE BARS INDICATE DIFFERENCES IN TOTAL *A. ODORATUM* COVER AMONG TREATMENTS.*NOTE SCALE WITH MAXIMUM OF 50%. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

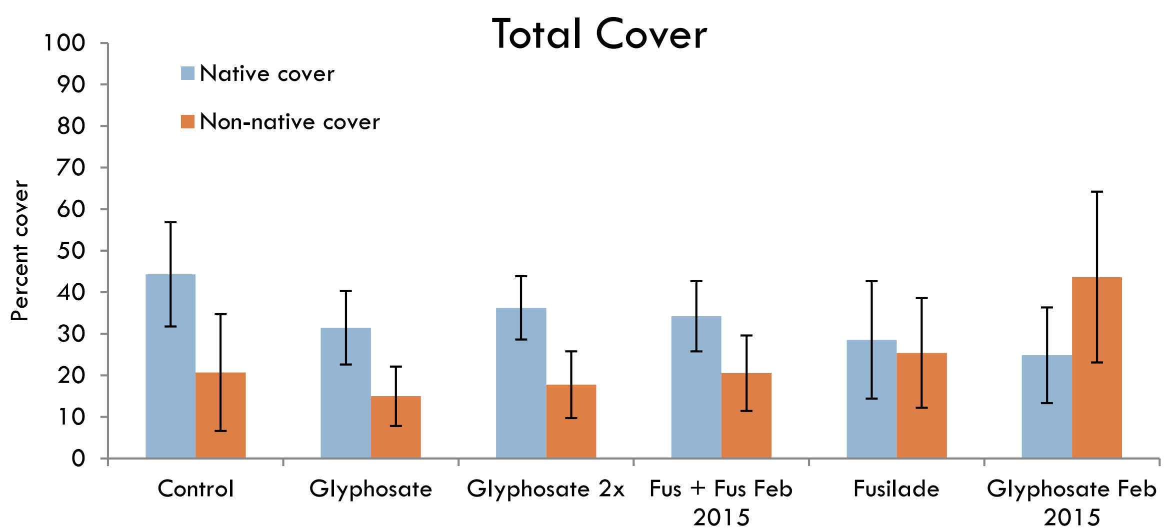



**FIGURE 6. TOTAL NATIVE AND NON-NATIVE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. NO SIGNIFICANT DIFFERENCES WERE FOUND FOR TOTAL NATIVE NOR NON-NATIVE SPECIES COVER BETWEEN TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

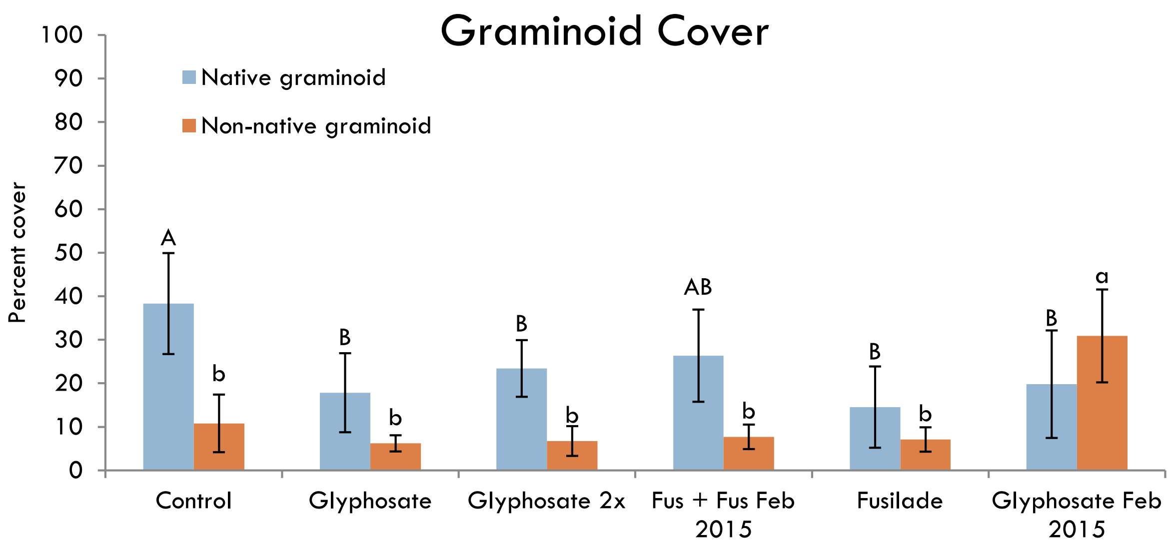



**FIGURE 7. NATIVE AND EXOTIC GRAMINOID COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERENCES IN TOTAL NATIVE GRAMINOID COVER AMONG TREATMENTS. LOWERCASE LETTERS ABOVE ORANGE BARS INDICATE DIFFERENCES IN TOTAL NON-NATIVE COVER AMONG TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

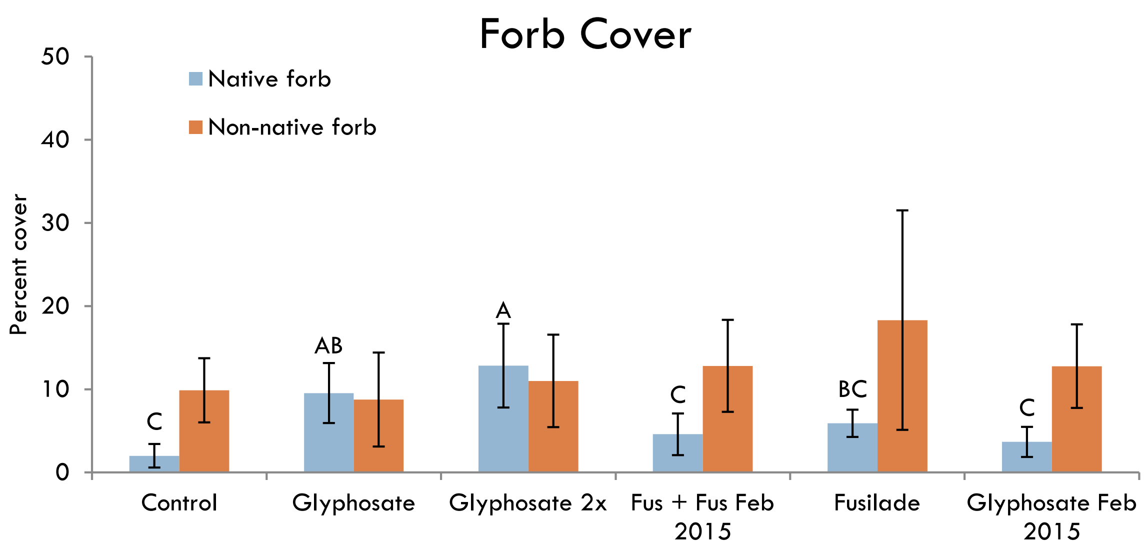



**FIGURE 8. NATIVE AND EXOTIC FORB COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERENCES IN TOTAL NATIVE FORB COVER AMONG TREATMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND FOR TOTAL NON-NATIVE FORB COVER AMONG TREATMENTS.*NOTE SCALE WITH MAXIMUM OF 50%. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

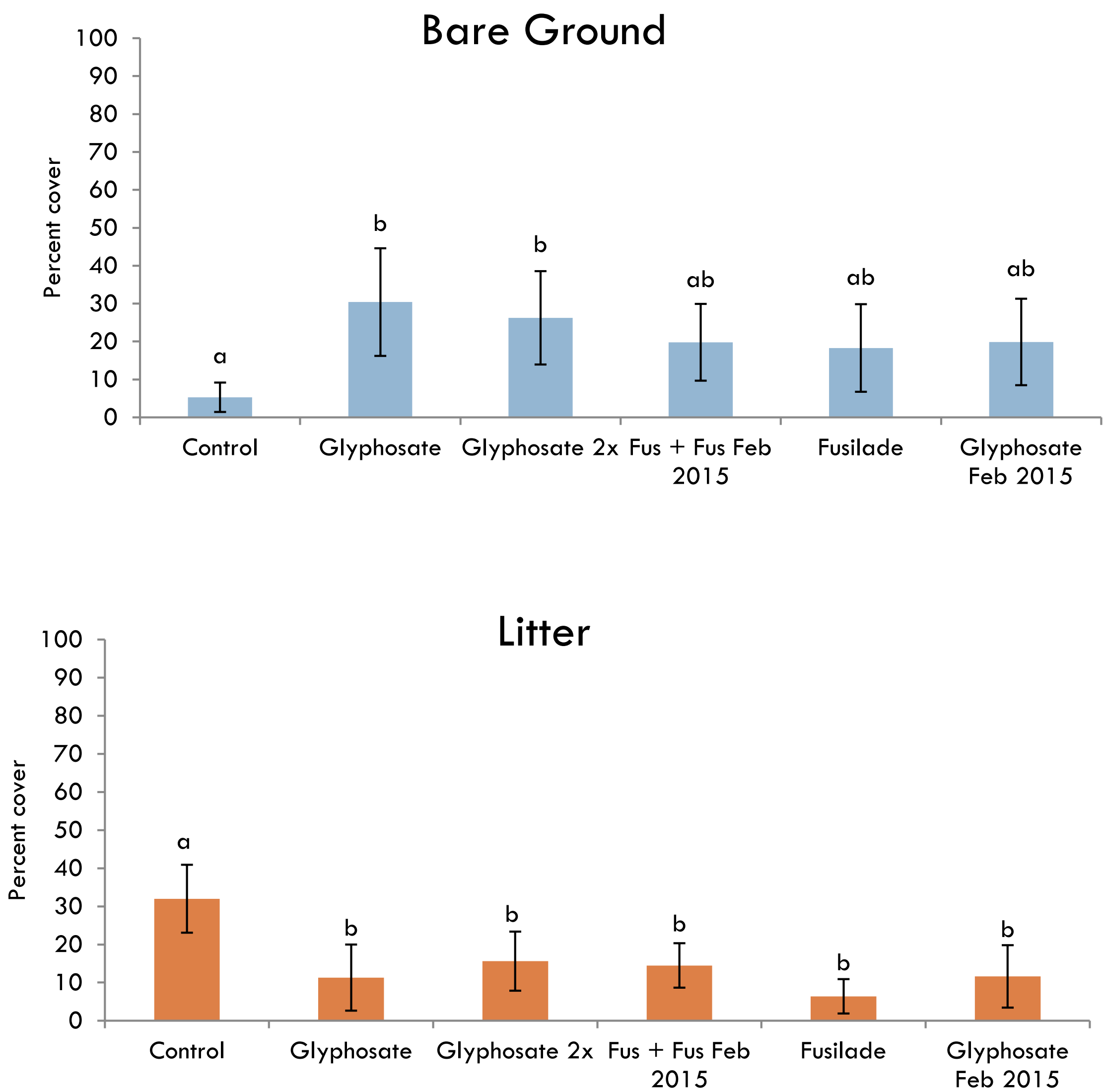



**FIGURE 9. BARE GROUND COVER (ABOVE) POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. LOWERCASE LETTERS ABOVE BARS INDICATE DIFFERENCES IN TOTAL BARE GROUND COVER AMONG TREATMENTS. LITTER COVER (BELOW) POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. LOWERCASE LETTERS ABOVE BARS INDICATE DIFFERENCES IN TOTAL LITTER COVER AMONG TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

## Fisher Butte

We found 52 vascular plant species pre-treatment in 2014 (Appendices G, H); in post-treatment monitoring, 44 species were found in 2016 and 55 species were found in 2018 (Appendix I). There were no significant differences in the average species richness between treatments in 2018 ($p=0.886$).

### *Anthoxanthum odoratum*

Cover of *A. odoratum* ranged from 8% to 15%, and did not vary significantly between treatments ($p=0.535$; Figure 10).

### Nativity

Native cover ranged from 15% to 32% and varied significantly between treatments ($p<0.0001$). Control plots had significantly higher native cover than any other treatment plots (Figure 11). Among the treated plots, the burn + 1 application of glyphosate plots had higher native cover than the burn + fusilade 2x plots and the burn + glyphosate (Feb 2015) plots (Figure 11). Exotic cover ranged from 25% to 45% but did not vary significantly between treatments ($p=0.516$; Figure 11).

### Graminoid Cover

Native graminoid cover ranged from 4% to 25% and was significantly higher in control plots than in any of the treated plots ($p<0.0001$; Figure 12). Exotic graminoid cover ranged from 8% to 16%, but did not vary significantly between treatments ($p=0.391$; Figure 12).

### Forb Cover

Native forb cover ranged from 5% to 14%, and varied significantly among treatments ($p=0.005$). The burn + 1 application of glyphosate had significantly higher native forb cover than the control and burn + glyphosate (Feb 2015) treatments (Figure 13). Exotic forb cover ranged from 16% to 35% but did not vary significantly between treatments ($p=0.167$; Figure 13).

### Substrate

Bare ground cover ranged from 30% to 49% and did not differ between treatments ($p=0.374$; Figure 14). Litter cover ranged from 6% to 12% and also did not differ between treatments ($p=0.103$; Figure 14).

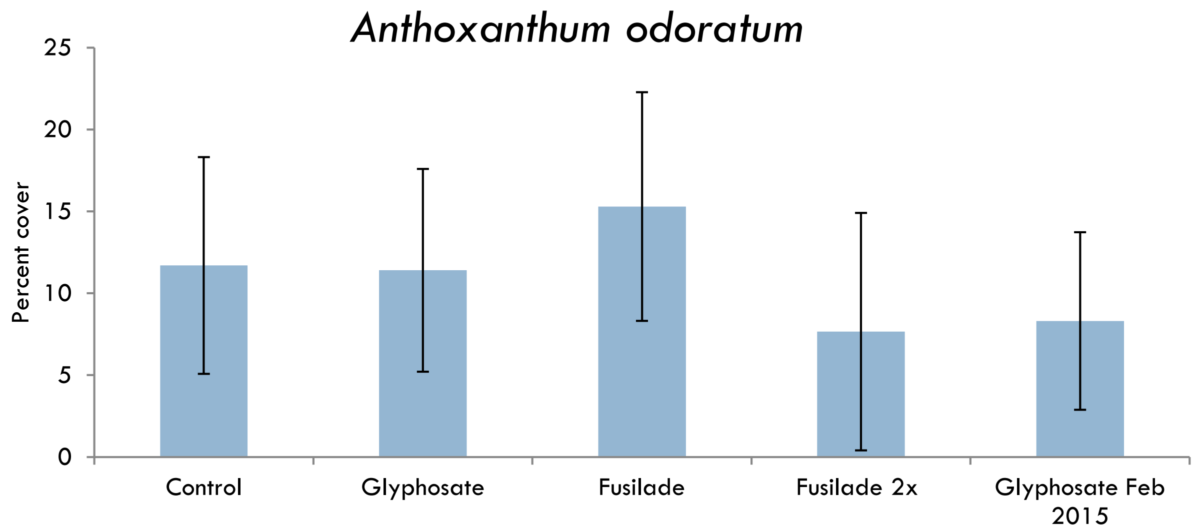



**FIGURE 10. *ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT FISHER BUTTE IN 2018. NO SIGNIFICANT DIFFERENCES WERE FOUND IN TOTAL *A. ODORATUM* COVER AMONG TREATMENTS. *NOTE SCALE WITH MAXIMUM OF 25%. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

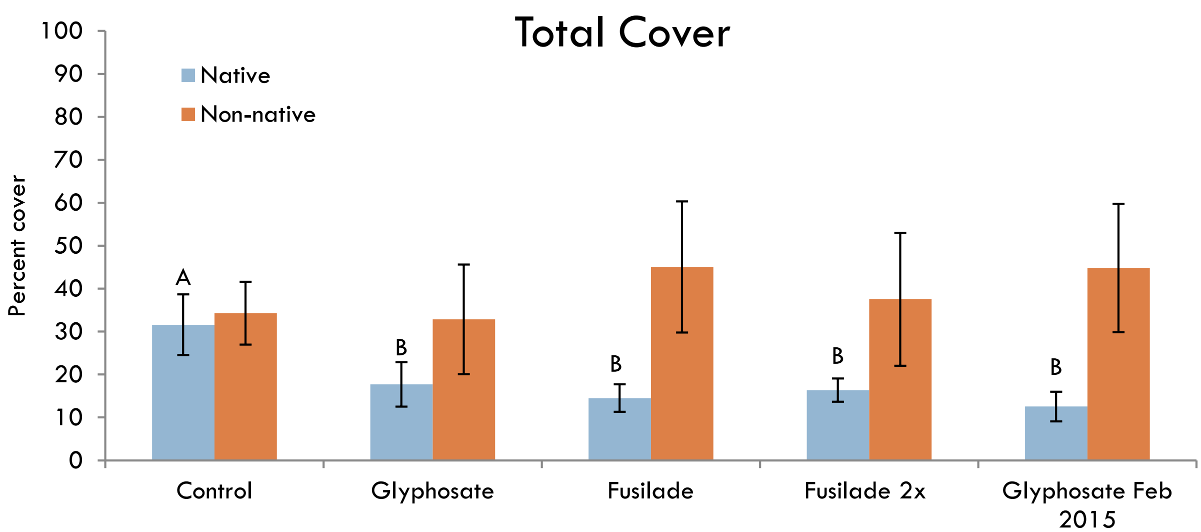



**FIGURE 11. TOTAL NATIVE AND NON-NATIVE PLANT COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2018. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERENCES IN TOTAL NATIVE COVER AMONG TREATMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND IN TOTAL EXOTIC COVER AMONG TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

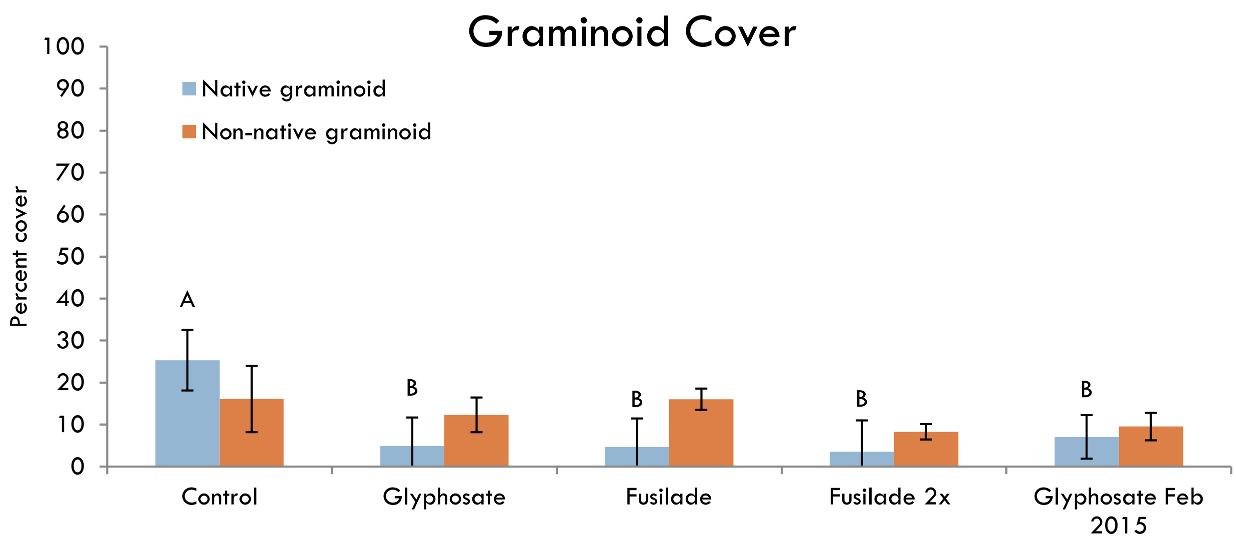



**FIGURE 12. NATIVE AND EXOTIC GRAMINOID COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2018. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE GRAMIMOID COVER AMONG TREATMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND IN TOTAL EXOTIC GRAMINOID COVER AMONG TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

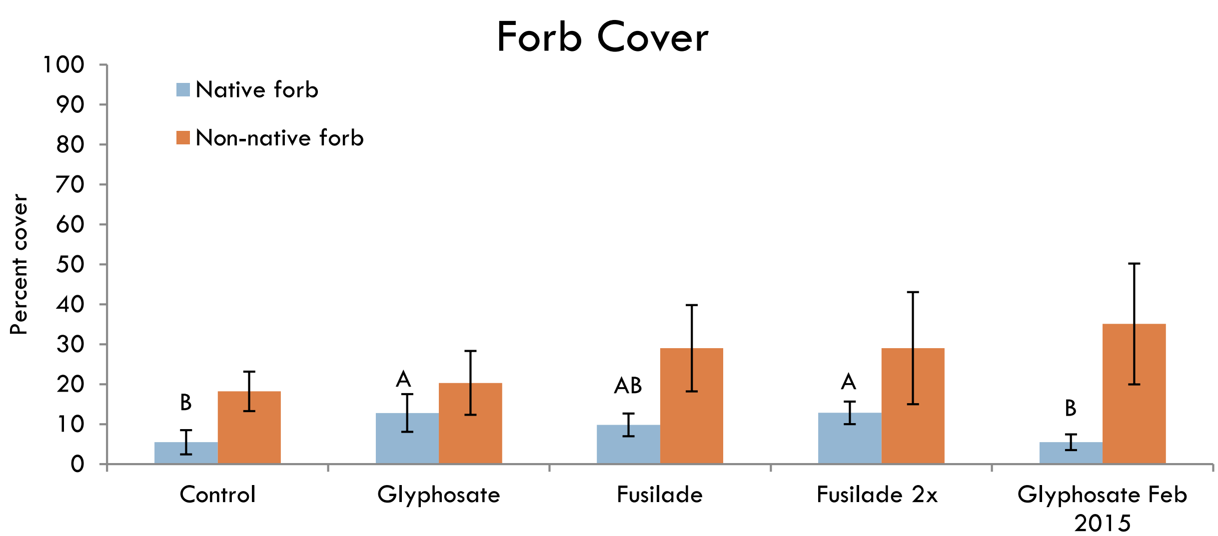
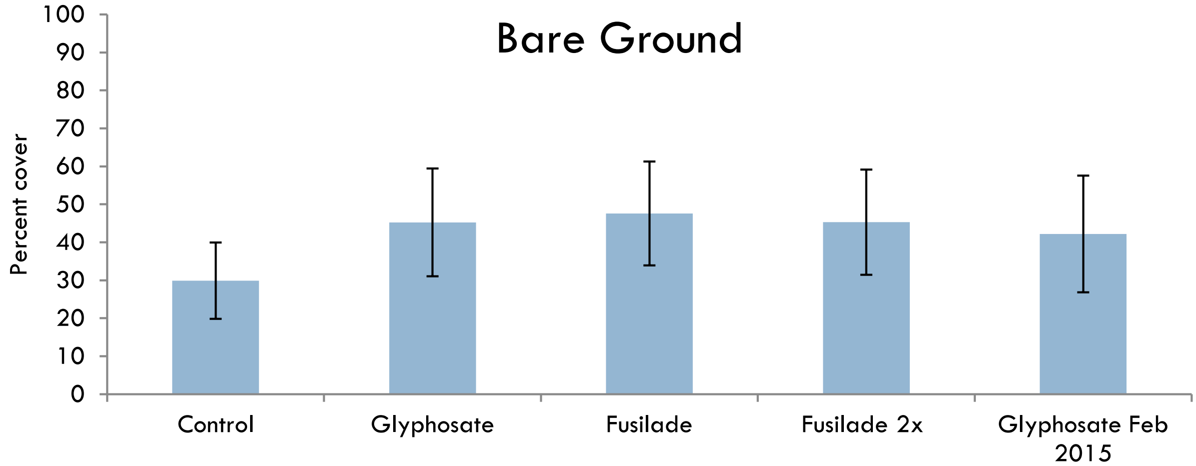



**FIGURE 13. NATIVE AND EXOTIC FORB COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2018. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERENCES IN TOTAL NATIVE FORB COVER AMONG TREATMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND IN NON-NATIVE FORB COVER AMONG TREATMENTS. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**



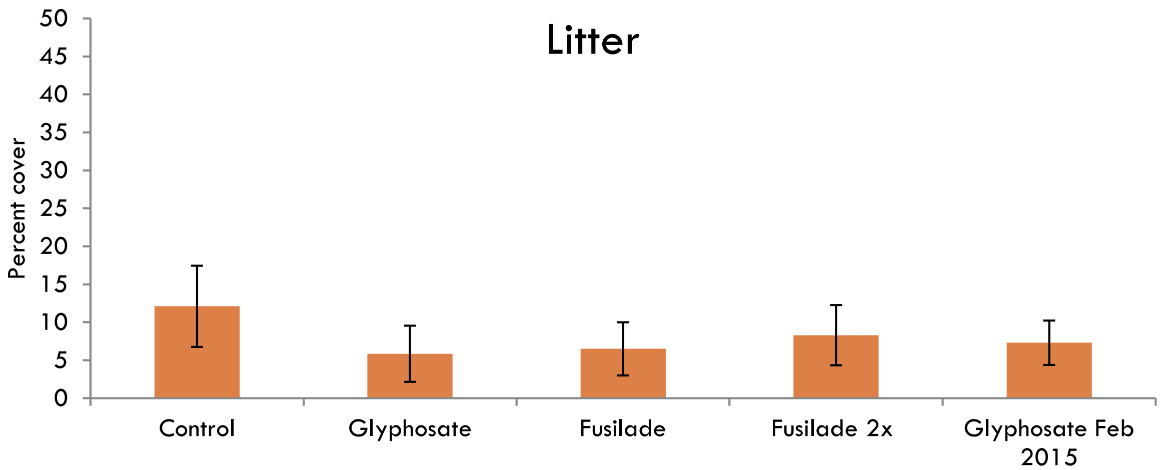




**FIGURE 14. BARE GROUND (ABOVE) AND LITTER (BELOW) COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2018. THERE WERE NO SIGNIFICANT DIFFERENCES FOUND IN TOTAL BARE GROUND OR LITTER COVER AMONG TREATMENTS. *NOTE SCALE WITH MAXIMUM OF 50% FOR LITTER COVER. ERROR BARS INDICATE 95% CONFIDENCE INTERVALS.**

# DISCUSSION

Rose Prairie and Fisher Butte are relatively high quality wetland prairies with moderately diverse native plant communities and few exotic species. That said, aggressive, fire-tolerant, exotic grasses still pose a risk to remnant wetland prairies such as these in the Fern Ridge RNA. One such grass, *Anthoxanthum odoratum*, has been identified as a target species at both Rose Prairie and Fisher Butte and developing efficient management strategies to reduce this and other exotic grasses while minimizing effects on non-target species will be essential to maintain and improve the quality of wetland prairies over the long term. The hydrologic and topographic conditions at each site make it a challenge to manage *A. odoratum*. *A. odoratum* was often documented growing out of the sides of the mounds of vegetation common at the sites, with much lower cover on the crowns of the mounds or in the space between the mounds. This makes it difficult to target *A. odoratum* with herbicides, as the plants are often shielded by other vegetation. While the treatments discussed here show potential for reducing *Anthoxanthum* cover, maintaining or increasing native plant cover, and reducing overall exotic plant cover, more experimentation is needed to develop the most effective management strategy or strategies.

## Rose Prairie

In 2015, herbicide application coincided with reduced *Anthoxanthum* cover, and glyphosate treatments appeared to be more effective than fusilade. The following year, *Anthoxanthum* cover remained low (less than 10%) in treated plots, but also declined in control plots, decreasing from 32% in 2015 to 4% in 2016 and reflecting the potential for non-management-related annual population fluctuations (Antonovics 1972). Across all plots, average *Anthoxanthum* cover has increased since 2016, and the burn + glyphosate (Feb 2015) treatment has had significantly higher *Anthoxanthum* cover than other treatments over the last two years, increasing from 4% cover in 2016 to 24% cover in 2017 and 31% cover in 2018. *Anthoxanthum* cover in control and other treatment plots remained under 15% in 2018.

From 2015 to 2016, cover of native graminoids in control plots increased while cover of exotic graminoids (mainly composed of *A. odoratum*) decreased. *Anthoxanthum* cover was significantly lower in the control plots in 2016, potentially opening up niche space for native grasses to establish. For example, *Deschampsia caespitosa*, a native bunch grass, doubled in cover across control plots from 2015 to 2016. Treated plots in 2016 followed a similar trend with relatively high native graminoid cover and lower exotic graminoid cover, suggesting a shift in graminoid community composition from roughly equal native and exotic graminoid cover, as observed in 2015, to a graminoid community dominated by natives. This native-dominated trend carried over into 2017 and 2018, except in burn + glyphosate (Feb 2015) treatment plots. In both years, burn + glyphosate (Feb 2015) treated plots had significantly higher exotic graminoid cover (again, mainly composed of *A. odoratum*) than other treatments, including the control.

After an initial post-treatment increase, native forb cover in all plots at Rose Prairie decreased over the last three years. Exotic forb cover (mainly composed of *Hypochaeris radicata*) generally decreased from 2016 to 2017, but remained slightly higher than native forb cover, potentially limiting the area available for native forbs to establish. Over time, there were no clear differences in native or exotic forb responses among herbicide treatments.

## Fisher Butte

*Anthoxanthum* cover has generally increased across treatments from 2015 to the present, though average cover in 2018 remained lower than pre-treatment levels, and variation in control plots from year to year again reflect the annual fluctuation of the population's reproductive success. Both glyphosate and fusilade treatments appeared to reduce *Anthoxanthum* cover, but double applications of both herbicides coincided with greater initial reductions in cover. Thus in the short term, both glyphosate and fusilade application reduce *Anthoxanthum* cover, but single applications may allow for a more rapid recovery of the species. Contrary to the rapid recovery observed in glyphosate-treated plots, the burn + two applications of fusilade treatment maintained a low cover of *Anthoxanthum* (below 3%) from 2015 to 2017. Fusilade is a more resilient herbicide than glyphosate (i.e. persists in the soil longer), meaning residuals from the herbicide application may have continued to impact *Anthoxanthum* cover for a longer period after initial application. In 2018, we observed increases in *Anthoxanthum* cover across all treatments except the burn + glyphosate (Feb 2015).

In contrast to 2016 and 2017, the graminoid community at Fisher Butte was dominated by exotic species in 2018, after major native species declines and slight exotic species increases across treatments. As in prior years, control plots had significantly higher native graminoid cover than all other treatments, but exotic graminoid cover showed no significant difference between treatments in 2018.

Forb cover from 2015 to 2016 doubled in the burn + one application of glyphosate treatment, and increased over five-fold in the burn + glyphosate (Feb 2015) treatment for both natives and exotics, possibly reflecting the short term effect of glyphosate and the resilience of forbs to recover from glyphosate application. Little change in native forb cover was observed in fusilade treatments between 2015 and 2016, but exotic forb cover (composed primarily of *H. radicata*) increased significantly. In 2017, exotic forb cover remained stable in the glyphosate treatments, but declined in fusilade treatments, while native forb cover declined in glyphosate treated plots. No significant changes were observed from 2017 to 2018. All treatments in 2018 had greater exotic forb cover than native forb cover, paralleling the pattern observed in 2016 and 2017.

### Conclusions

At both wet prairie sites, differences in *Anthoxanthum* cover over time may reflect annual population fluctuations in reproduction and mortality (Antonovics 1972), responses to management actions such as burning and direct herbicide application, and responses to hydrologic events or other abiotic factors. While the treatments discussed here show promise for long-term management, it is difficult to distinguish effects of management treatments from those of environmental factors or random fluctuations in our target species' population. The hydrologic and topographic conditions at each site present unique challenges to management of *A. odoratum*. A better understanding of plant population fluctuations through time, especially in response to environmental factors, will be valuable information for guiding future experimental efforts and for determining the best management plan for invaded wetland prairie sites in the Fern Ridge RNA.

# LITERATURE CITED

Antonovics, J. 1972. Population dynamics of the grass *Anthoxanthum odoratum* on a zinc mine. Journal of Ecology 60: 351–365.

Bois, S.T. 2012. Controlling exotic grasses while maintaining native plant communities in fire-maintained wet prairies: 2012 progress report. Institute for Applied Ecology, Corvallis, Oregon for U.S. Army Corps of Engineers, Willamette Valley Projects: iii + 18pp.

Boyer, L. 2008. Krautmann Jefferson Farm Oak and Prairie Habitat Restoration Project. LIP Progress Report, Willamette Valley, Oregon. Available from http://www.heritageseedlings.com/shop/wpimages/jefferson-farm-restoration-2008-report.pdf [accessed 25 October 2018].

Floberg, J., Goering, M., Wilhere, G., MacDonald, C., Chappell, C., Rumsey, C., Ferdana, Z., Holt, A., Skidmore, P., Horsman, T., Alverson, E., Tanner, C., Bryer, M., Iachetti, P., Harcombe, A., McDonald, T., Cook, T., Summers, M., and Rolph, D. 2004. Willamette Valley-Puget Trough-Georgia Basin Ecoregional Assessment, Volume One: Report. The Nature Conservancy with support from the Nature Conservancy of Canada, Washington Department of Fish and Wildlife, Washington Department of Natural Resources (Natural Heritage and Nearshore Habitat programs), Oregon State Natural Heritage Information Center and the British Columbia Conservation Data Centre.

Noss, R.F., LaRoe III, E.T., and Scott, J.M. 1995. Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation. Biological Report. Available from http://er.uwpress.org/lookup/doi/10.3368/er.14.1.95 [accessed 10 October 2018].

Pfeifer-Meister, L., Bridgham, S.D., Roy, B.A., Johnson, B.R., Kreuger, J., and Wold, E. 2007. Testing the Effectiveness of Site Preparation Techniques for Wetland Prairie Restoration. City of Eugene, Eugene, Oregon.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from https://www.R-project.org/.

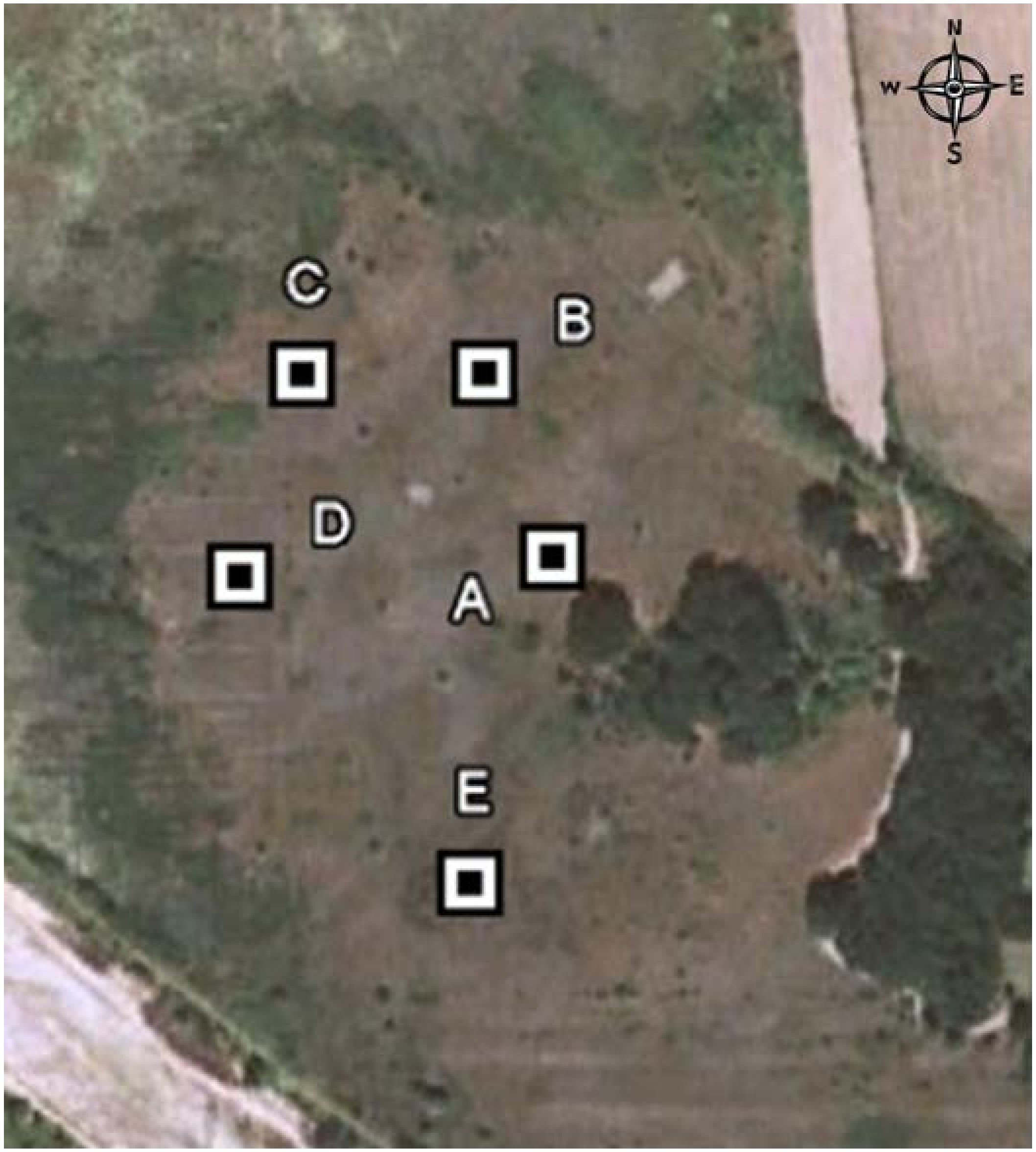
Stanley, A.G., Kaye, T.N., and Dunwiddie, P.W. 2008. Regional strategies for restoring invaded prairies: observations from a multisite collaborative research project. Native Plants Journal 9(3): 247–254. doi:10.2979/NPJ.2008.9.3.247.

Stanley, A.G., Kaye, T.N., and Dunwiddie, P.W. 2010. Regional Strategies for Restoring Invaded Prairies. Final report: 40.

Tesfamariam, T., Bott, S., Cakmak, I., Römheld, V., and Neumann, G. 2009. Glyphosate in the rhizosphere—Role of waiting times and different glyphosate binding forms in soils for phytotoxicity to non-target plants. European Journal of Agronomy 31(3): 126–132. doi:10.1016/j.eja.2009.03.007.

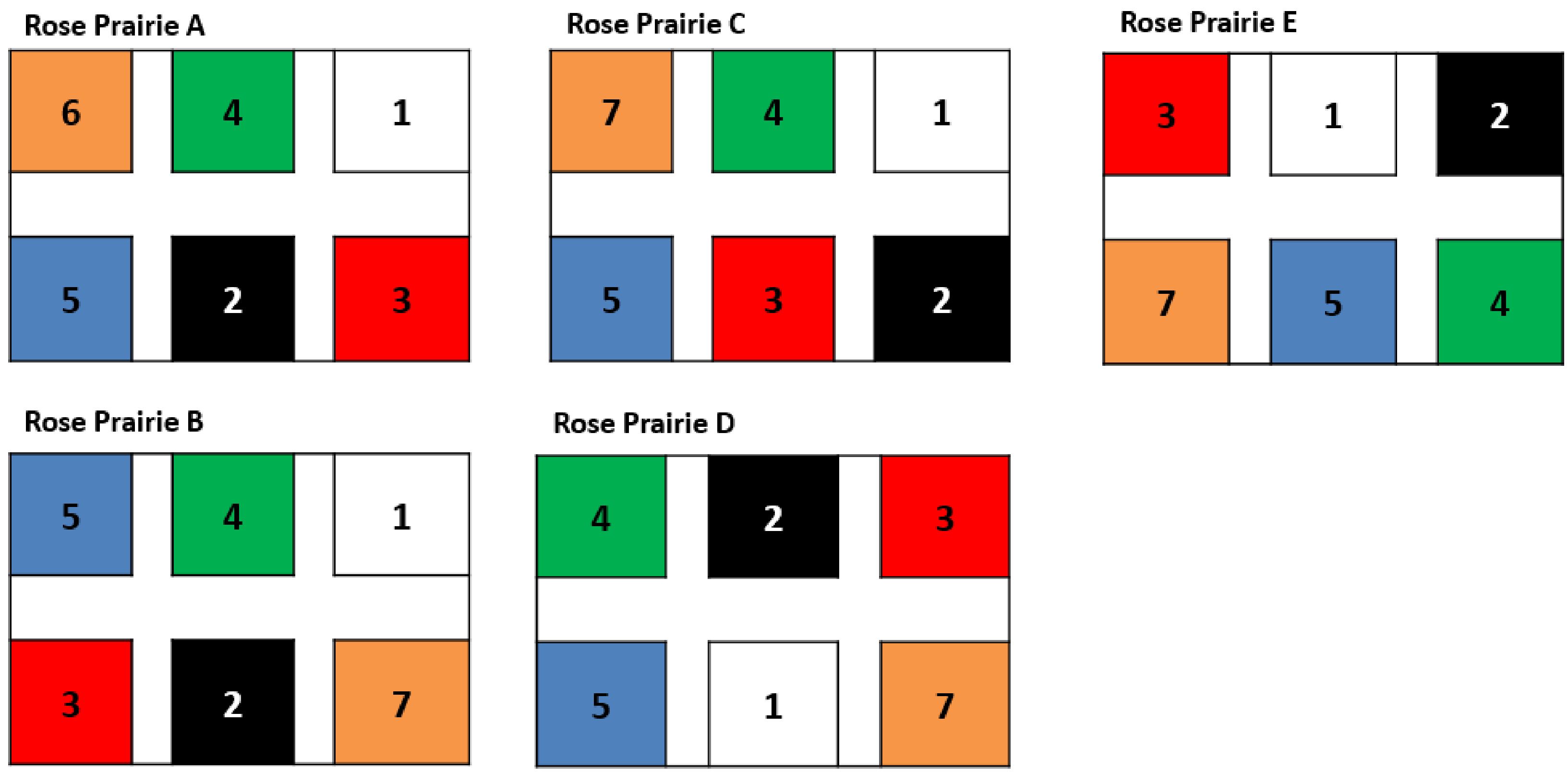
U.S. Fish and Wildlife Service. 2010. Recovery Plan for the Prairie Species of Western Oregon and Southwestern Washington. U.S. Fish and Wildlife Service, Portland, Oregon.

# APPENDIX A. ROSE PRAIRIE MAP, PLOT LOCATIONS, AND TREATMENT ASSIGNMENTS




Locations of Rose Prairie macroplots. Origins (tall conduit or rebar) are in the NE corner, except for plot D, where the origin is in the NW corner.

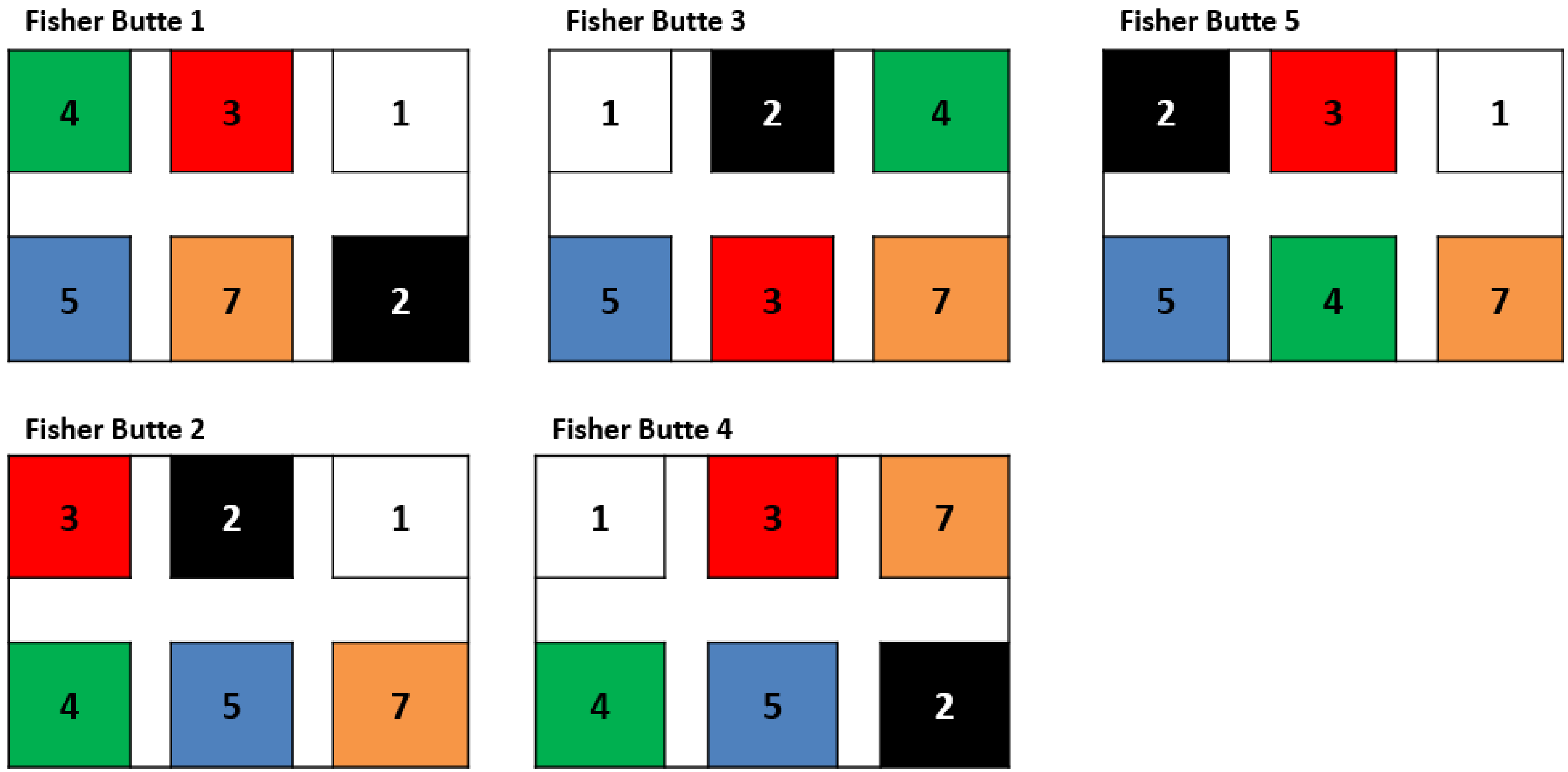
| Plot | Coordinates (WGS 84) | |
|---|---|---|
| A | 44.08658260 | -123.24841065 |
| B | 44.08724444 | -123.24875331 |
| C | 44.08724142 | -123.24967104 |
| D | 44.08651228 | -123.24998427 |
| E | 44.08540637 | -123.24882522 |




**Treatments**

| | |
|---|---|
| 1 | Control |
| 2 | Glyphosate 1-2 weeks post-fire |
| 3 | Glyphosate 1-2 weeks post fire & Feb. Glyphosate |
| 4 | Fusilade 1-2 weeks post-fire (received follow-up application of Fusilade in Feb. 2015 → "Fus + Fus Feb. 2015") |
| 5 | Fusilade 1-2 weeks post fire & Fusilade Feb. 2015<br>(only received initial application of Fusilade; 2nd application of Fusilade did not take place in Feb. 2012 or 2015) |
| 6 | Surfactant Only (Removed from analysis due to only having single sample) |
| 7 | Glyphosate Feb. 2015 (Inadvertently applied to "Surfactant Only" plots) |

# APPENDIX B. FISHER BUTTE MAP, PLOT LOCATIONS, AND TREATMENT ASSIGNMENT




**Treatments**

| | |
|---|---|
| 1 | Control |
| 2 | Glyphosate 1-2 weeks post-fire |
| 3 | Glyphosate 1-2 weeks post fire & Feb. Glyphosate (2nd application of Glyphosate didn't occur; Trt #2 + 3 combined for analysis) |
| 4 | Fusilade 1-2 weeks post-fire |
| 5 | Fusilade 1-2 weeks post fire & Fusilade Feb. 2015 |
| 6 | Surfactant Only (Removed from analysis → see below) |
| 7 | Glyphosate Feb. 2015 (Inadvertently applied to "Surfactant Only" plots) |

# APPENDIX C. AVERAGE COVER OF ALL SPECIES OBSERVED IN MONITORING PLOTS AT ROSE PRAIRIE IN 2010.

| | Block | | | | |
|---|---|---|---|---|---|
| **Species** | **A** | **B** | **C** | **D** | **E** |
| *Agrostis* spp. | 5.75 | 11 | 5.33 | 7.83 | 3.85 |
| *Aira caryophyllea* | -- | 0.02 | -- | -- | -- |
| *Anthoxanthum odoratum* | 12.67 | 7.33 | 10.17 | 7.83 | 8.5 |
| *Aster curtus* | -- | -- | 0 | 0.17 | 1.67 |
| *Aster hallii* | 0.08 | 0.02 | 0.08 | 0.2 | 0.35 |
| *Brodiaea hyacinthina* | 0 | 0.1 | 0.03 | 0.03 | 0.13 |
| *Camassia quamash* | 0.43 | 0.6 | 0.43 | 0.83 | 0.2 |
| *Carex leporina* | 1.42 | 0.18 | 0.43 | 0.43 | 0.18 |
| *Carex rossii* | -- | 0.5 | 0.17 | 0 | 0.35 |
| *Centaurea pratensis* | -- | -- | 1.67 | -- | -- |
| *Comandra umbellata* | -- | -- | 0 | 0 | 0.08 |
| *Crataegus douglasii* | -- | 0.33 | 0 | 0.02 | 0.08 |
| *Danthonia californica* | 3.5 | 4 | 5.83 | 0.67 | 0.67 |
| *Deschampsia caespitosa* | 11.5 | 2.17 | 10 | 8.17 | 4 |
| *Epilobium* spp. | 0.08 | 0 | -- | -- | -- |
| *Eriophyllum lanatum* | 0.25 | 0.18 | 0.33 | 0.17 | 0.5 |
| *Fragaria virginiana* | -- | -- | -- | -- | 0.08 |
| *Galium parisiense* | -- | -- | 0.1 | 0 | 0.08 |
| *Gratiola ebracteata* | -- | 0.05 | 0.03 | 0.02 | 0.05 |
| *Grindelia integrifolia* | 0.35 | 2.83 | 1 | 2.17 | 0.33 |
| *Hypericum perforatum* | 0.02 | 0.03 | -- | 0.08 | 0.08 |
| *Hypochaeris radicata* | 1.17 | 1.83 | 0.92 | 1.02 | 0.5 |
| *Juncus bufonius* | -- | 0.5 | 0.92 | 0.5 | 0.42 |
| *Juncus* ssp. | -- | -- | 0.5 | -- | -- |
| *Juncus tenuis* | 0.05 | 0.12 | 0 | 0.08 | 0.08 |
| *Juncus nevadensis* | 5.33 | 2.58 | 0.17 | 0.1 | 0.25 |
| *Lomatium bradshawii* | -- | -- | 0 | 0 | 0.03 |
| *Lotus formosissimus* | 1.08 | 0.5 | 1.83 | 1.58 | 0.6 |
| *Lotus unifoliolatus* | -- | -- | 0 | 0.02 | -- |
| *Luzula campestris* | -- | -- | 0.02 | -- | -- |
| *Microseris laciniatus* | 0.42 | 0.67 | -- | -- | -- |

| | | | | | |
|---|---|---|---|---|---|
| *Myosotis discolor* | 0.08 | 0 | -- | -- | -- |
| *Panicum occidentalis* | -- | 5.17 | 3.42 | 11.67 | 15.83 |
| *Plantago lanceolata* | -- | -- | 0 | 0.02 | -- |
| *Prunella vulgaris* | -- | -- | 0.08 | 0.33 | 0.27 |
| *Rosa* sp. | -- | -- | 0.67 | 0 | 1.42 |
| *Sisyrinchium angustifolium* | 0.08 | 0.02 | 0.08 | 0.02 | 0.33 |
| *Solidago* spp. | -- | -- | 0.17 | 0.5 | 0.08 |
| *Trifolium dubium* | -- | 0.08 | 0 | 0.03 | 0.1 |
| *Vaccinium caespitosum* | -- | -- | 0 | 0 | 8.67 |
| *Viola odorata* | -- | -- | 0 | 0 | 0.02 |
| *Zigadenus venenosus* | -- | -- | 0.02 | 0.02 | -- |

*Dashes indicate that a species was not present in the plots when monitored. A zero indicates the species was present, but at levels below the number of significant digits reported.

# APPENDIX D. AVERAGE COVER OF ALL SPECIES OBSERVED IN PLOTS AT ROSE PRAIRIE IN 2018.

| | Treatment | | | | | |
|---|---|---|---|---|---|---|
| **Species** | **Control** | **Glyphosate** | **Glyphosate 2X** | **Fusilade** | **Fus + Fus Feb 2015** | **Glyphosate Feb 2015** |
| *Agoseris grandiflora* | 0.06 | 0.13 | 0.04 | 0.17 | 0.13 | 0.02 |
| *Allium acuminatum* | -- | -- | -- | 0.01 | -- | 0.01 |
| *Anthoxanthum odoratum* | 10.80 | 6.21 | 9.20 | 7.10 | 7.71 | 25.12 |
| *Aster curtus (Seriocarpus rigidus)* | -- | -- | -- | -- | -- | 0.01 |
| *Camassia quammash* | 0.76 | 1.31 | 1.62 | 1.61 | 1.04 | 1.47 |
| *Centaurea pratensis* | 1.01 | -- | -- | -- | -- | -- |
| *Danthonia californica* | 0.01 | -- | 0.01 | 0.01 | 0.30 | 0.01 |
| *Deschampsia caespitosa* | 33.90 | 6.00 | 13.91 | 3.90 | 21.70 | 17.51 |
| *Epilobium* sp. | 0.01 | 0.01 | 0.02 | 0.02 | -- | -- |
| *Eriophyllum lanatum* | 0.31 | 6.41 | 7.00 | 2.56 | 1.61 | 0.73 |
| *Fragaria* sp. | 0.10 | -- | -- | -- | -- | -- |
| *Fraxinus* sp. | -- | 0.10 | -- | -- | -- | -- |
| *Gratiola ebracteata* | 0.01 | -- | 0.01 | -- | -- | -- |
| *Grindellia integrifolia* | 0.40 | 1.26 | 1.20 | 0.62 | 0.74 | 0.92 |
| *Hypericum perforatum* | -- | -- | -- | 0.01 | -- | -- |
| *Hypochaeris radicata* | 8.50 | 8.76 | 10.90 | 17.70 | 12.80 | 11.80 |
| *Juncus bufonius* | 0.11 | 0.64 | 0.42 | 0.63 | 0.64 | 0.22 |
| *Juncus nevadensis* | -- | 0.20 | -- | -- | -- | -- |
| *Juncus tenuis* | 4.30 | 11.00 | 7.70 | 10.00 | 3.71 | 4.51 |
| *Lomatium bradshawii* | -- | -- | -- | 0.01 | -- | -- |
| *Lotus formosissimus* | 0.10 | 0.06 | 0.54 | 0.50 | 0.22 | 0.37 |
| *Madia* sp. | -- | -- | 0.02 | -- | -- | -- |
| *Mentha pulegium* | 0.10 | -- | -- | -- | -- | -- |
| *Microseris laciniata* | -- | -- | 0.05 | -- | -- | 0.30 |
| *Microsteris gracilis* | -- | -- | 0.05 | -- | -- | 0.30 |
| *Navarretia* sp. | -- | -- | -- | 0.01 | -- | -- |
| *Panicum occidentale* | -- | -- | 0.10 | -- | -- | -- |
| *Plantago lanceolata* | 0.25 | -- | 0.01 | 0.60 | 0.01 | -- |
| *Prunella vulgaris* | 0.06 | -- | -- | -- | -- | -- |
| *Rosa* sp. | 0.90 | 2.80 | -- | 1.70 | 0.40 | 1.00 |
| *Sherardia arvensis* | 0.01 | -- | -- | -- | -- | 0.02 |
| *Sisyrinchium angustifolium* | -- | 0.05 | 0.01 | 0.07 | 0.03 | 0.01 |
| *Solidago* spp. | 0.20 | 0.30 | -- | 0.31 | 0.40 | 0.60 |
| *Vaccinium caespitosum* | 4.00 | 4.00 | 0.50 | 8.10 | 3.30 | 1.10 |
| *Viola odorata* | -- | -- | -- | 0.01 | -- | -- |
| *Zigadenus venonosus* | 0.10 | 0.02 | -- | 0.02 | 0.40 | 0.01 |

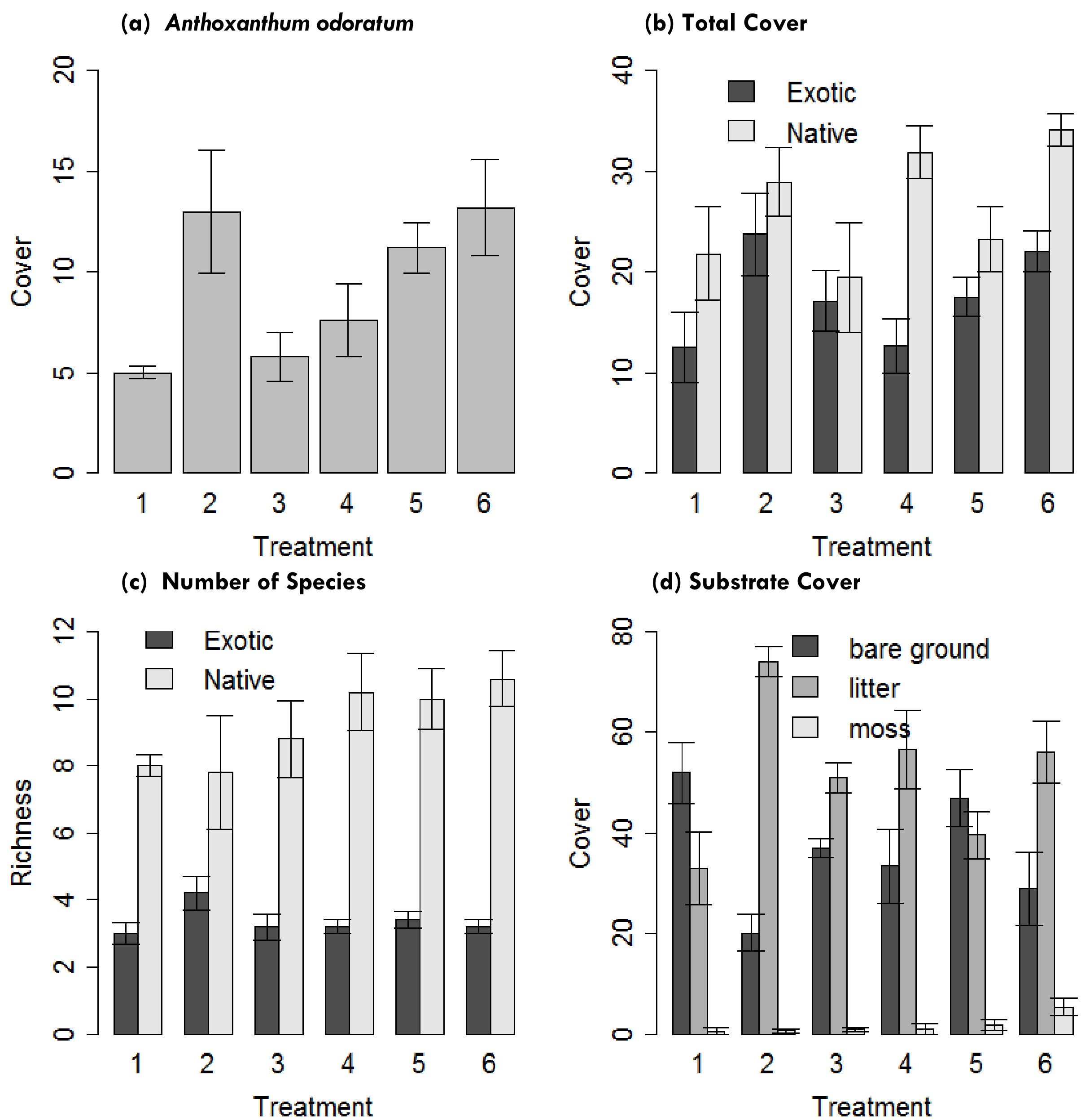
*Dashes indicate that a species was not present in the plots when monitored. A zero indicates the species was present, but at levels below the number of significant digits reported.

# APPENDIX E. AVERAGE COVER OF ALL SUBSTRATES OBSERVED IN MONITORING PLOTS AT ROSE PRAIRIE IN 2010 AND FISHER BUTTE IN 2014.

| | Rose Prairie Blocks | | | | |
|---|---|---|---|---|---|
| Substrate | A | B | C | D | E |
| Bare ground | 30.5 | 40.8 | 39.2 | 29.7 | 42.0 |
| Litter | 61.7 | 46.7 | 48.8 | 55.5 | 45.8 |
| Moss | 0.2 | 2.8 | 2.0 | 1.4 | 2.3 |

| | Fisher Butte Blocks | | | | |
|---|---|---|---|---|---|
| Substrate | 1 | 2 | 3 | 4 | 5 |
| Bare ground | 23.6 | 15.4 | 14.3 | 29.8 | 21.8 |
| Litter | 36.1 | 33.1 | 36.4 | 26.1 | 45.3 |
| Moss | 1.4 | 3.3 | 1.6 | 3.5 | 0.0 |

# APPENDIX F. SUMMARY OF PRE-TREATMENT MONITORING DATA OF EXPERIMENTAL PLOTS AT ROSE PRAIRIE (2010). (A) COVER OF *ANTHOXANTHUM ODORATUM*, (B) TOTAL PLOT COVER OF NATIVE AND EXOTIC PLANT, (C) NUMBER OF NATIVE AND EXOTIC SPECIES PER PLOT, AND (D) COVER OF BARE GROUND. DATA ARE MEANS ± 1SE.



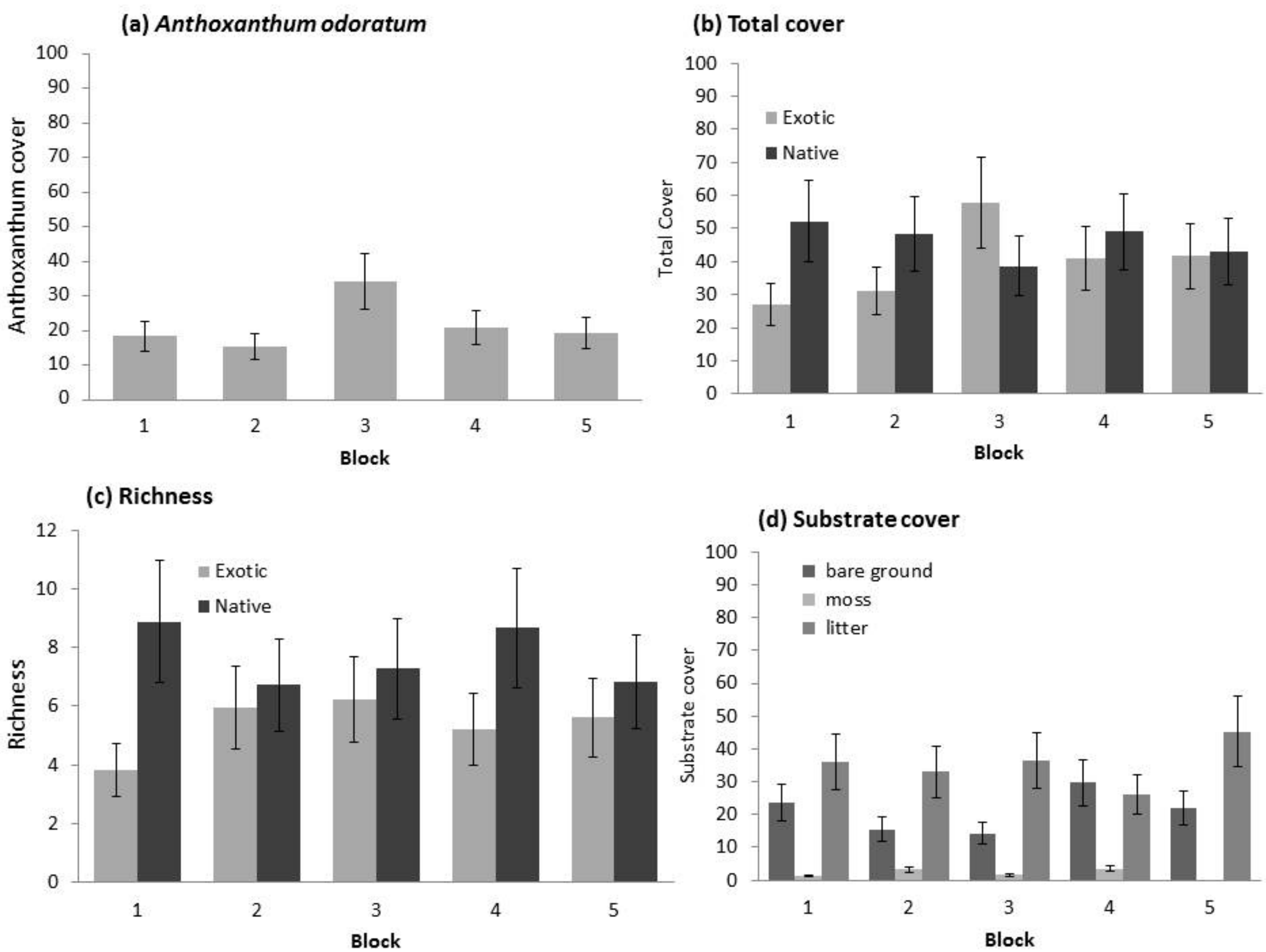
# APPENDIX G. AVERAGE COVER OF ALL SPECIES OBSERVED IN PRE-TREATMENT MONITORING PLOTS AT FISHER BUTTE IN 2014.

| | Block | | | | |
|---|---|---|---|---|---|
| **Species** | **1** | **2** | **3** | **4** | **5** |
| *Agrostis* spp. | 0.78 | 0.22 | 0.03 | 0.03 | 0.01 |
| *Aira caryophyllea* | 0.03 | 0.02 | 0.01 | -- | -- |
| *Allium acuminatum* | 1.29 | 0.39 | -- | -- | -- |
| *Allium amplectens* | -- | 0.26 | 1.22 | 2.28 | 0.54 |
| *Anthoxanthum odoratum* | 18.39 | 15.44 | 34.17 | 20.83 | 19.33 |
| *Aster hallii* | 0.36 | 0.74 | 0.33 | 0.62 | 1.02 |
| *Briza minor* | 0.34 | 0.14 | 0.58 | 0.67 | 0.63 |
| *Brodiaea hyacinthina* | 0.00 | 0.05 | 0.01 | 0.02 | 0.40 |
| *Brodiaea* sp. | 0.01 | -- | -- | -- | -- |
| *Bromus hordeaceus* | -- | -- | -- | -- | 0.01 |
| *Camassia quamash* | -- | 0.03 | 0.01 | 0.17 | 1.36 |
| *Carex leporina* | -- | -- | 0.08 | -- | -- |
| *Carex* sp. | 0.01 | -- | -- | -- | -- |
| *Centaurium erythraea* | 0.01 | 0.13 | 0.02 | 0.01 | 0.02 |
| *Cerastium glomeratum* | -- | 0.01 | -- | -- | -- |
| *Crataegus douglasii* | -- | -- | 0.06 | 0.03 | -- |
| *Danthonia californica* | 10.00 | 5.39 | 18.34 | 7.89 | 12.56 |
| *Deschampsia caespitosa* | 31.78 | 34.17 | 4.78 | 28.06 | 23.17 |
| *Epilobium* spp. | -- | -- | -- | -- | 0.02 |
| *Erigeron decumbens* | 0.11 | 0.01 | -- | 0.33 | -- |
| *Eriophyllum lanatum* | -- | -- | -- | 0.89 | -- |
| *Fraxinus latifolia* | -- | -- | 1.67 | 0.67 | -- |
| *Grindelia integrifolia* | 1.84 | 0.39 | 0.51 | 3.33 | 1.56 |
| *Holcus lanatus* | 0.01 | 1.66 | 0.28 | 0.55 | 0.79 |
| *Horkelia congesta* | -- | -- | -- | 0.22 | -- |
| *Hypericum perforatum* | -- | 0.07 | 0.04 | 0.04 | 0.27 |
| *Hypochaeris radicata* | 4.28 | 2.09 | 12.50 | 15.78 | 2.19 |
| *Juncus tenuis* | 1.54 | 1.07 | 3.34 | 0.15 | 1.36 |
| *Leucanthemum vulgare* | -- | -- | 0.06 | -- | -- |
| *Linum bienne* | 0.03 | -- | -- | -- | -- |
| *Lotus formosissimus* | 2.58 | 3.69 | 4.22 | 0.83 | -- |
| *Luzula campestris* | 0.06 | -- | -- | -- | 0.10 |
| *Mentha pulegium* | 3.28 | 9.17 | 7.83 | 2.41 | 17.89 |
| *Microseris laciniatus* | 0.16 | 0.07 | 0.38 | 0.25 | 0.12 |
| *Myosotis discolor* | 0.01 | 0.23 | 0.12 | -- | 0.03 |
| *Panicum occidentalis* | 0.76 | 0.19 | -- | 0.14 | -- |

| | | | | | |
|---|---|---|---|---|---|
| *Parentucellia viscosa* | -- | 0.01 | -- | -- | 0.01 |
| *Plagiobothrys* sp. | -- | -- | -- | -- | 0.01 |
| *Plantago lanceolata* | -- | -- | 0.06 | 0.14 | -- |
| *Potentilla gracilis* | -- | 0.01 | 0.19 | 0.69 | 0.19 |
| *Prunella vulgaris* | 1.04 | 1.53 | 3.17 | 2.00 | 0.42 |
| *Prunus avium* | -- | 0.22 | 0.39 | 0.01 | -- |
| *Rosa* sp. | 10.83 | 21.61 | 23.78 | 5.28 | 9.00 |
| *Rubus armeniacus* | -- | 0.22 | 0.28 | 0.34 | -- |
| *Rubus laciniatus* | -- | -- | -- | -- | 0.17 |
| *Rumex acetosella* | 0.01 | 0.17 | -- | 0.03 | -- |
| *Senecio jacobaea* | -- | 0.34 | 0.01 | 0.06 | 0.19 |
| *Sherardia arvensis* | 0.01 | 0.99 | 1.46 | 0.04 | 0.02 |
| *Sisyrinchium angustifolium* | 0.53 | 0.21 | 0.38 | 0.18 | 0.17 |
| *Vulpia bromoides* | -- | 0.03 | -- | -- | 0.22 |
| *Zigadenus venenosus* | 0.11 | 0.21 | -- | 0.34 | 0.06 |

*Dashes indicate that a species was not present in the plots when monitored. A zero indicates the species was present, but at levels below the number of significant digits reported.

# APPENDIX H. SUMMARY OF PRE-TREATMENT MONITORING DATA OF EXPERIMENTAL PLOTS AT FISHER BUTTE (2014). (A) COVER OF *ANTHOXANTHUM ODORATUM*, (B) TOTAL PLOT COVER OF NATIVE AND EXOTIC PLANT, (C) NUMBER OF NATIVE AND EXOTIC SPECIES PER PLOT, AND (D) COVER OF BARE GROUND. DATA ARE MEANS ± 1SE.



# APPENDIX I. AVERAGE COVER OF ALL SPECIES OBSERVED IN PLOTS AT FISHER BUTTE IN 2018.

| | Treatment | | | | |
|---|---|---|---|---|---|
| **Species** | **Control** | **Glyphosate** | **Fusilade** | **Fusilade 2x** | **Glyphosate Feb 2015** |
| *Agoseris grandiflora* | 0.86 | 2.68 | 1.35 | 3.25 | 0.95 |
| *Agrostis* sp. | 3.45 | 0.46 | 0.60 | 0.31 | 1.05 |
| *Aira caryophyllea* | 0.09 | 0.09 | 0.02 | 0.07 | 0.07 |
| *Allium acuminatum* | 0.11 | 0.81 | 0.71 | 1.30 | 0.46 |
| *Anthoxanthum odoratum* | 11.70 | 11.41 | 15.30 | 7.66 | 8.31 |
| *Aster hallii* | 0.26 | 1.78 | 2.05 | 1.81 | 0.56 |
| *Briza minor* | 0.29 | 0.15 | 0.05 | 0.14 | 0.05 |
| *Brodiaea hyacinthina* | -- | 0.45 | 0.01 | -- | 0.02 |
| *Bromus hordeaceus* | -- | 0.01 | -- | -- | -- |
| *Camassia quammash* | 0.07 | 0.67 | -- | 0.40 | 0.25 |
| *Castilleja tenuis* | -- | 0.11 | 0.01 | -- | -- |
| *Centaurium erythrea* | 0.01 | -- | 0.01 | 0.05 | 0.01 |
| *Cerastium glomeratum* | -- | -- | -- | 0.01 | -- |
| *Clarkia* sp. | -- | 0.05 | -- | 0.05 | 0.10 |
| *Danthonia californica* | 6.10 | 0.65 | 0.83 | 0.71 | 1.00 |
| *Deschampsia caespitosa* | 16.80 | 2.68 | 2.05 | 0.70 | 4.10 |
| *Eleocharis* sp. | -- | 0.62 | 0.01 | -- | 0.08 |
| *Epilobium minutum* | -- | -- | 0.01 | 0.01 | 0.31 |
| *Epilobium* sp. | -- | -- | -- | 0.05 | -- |
| *Erigeron decumbens* | -- | 0.30 | -- | -- | -- |
| *Eriophyllum lanatum* | 0.06 | 0.08 | 0.20 | 0.61 | -- |
| *Fraxinus* sp. | 0.80 | -- | -- | -- | -- |
| *Galium parisiense* | -- | 0.01 | 0.01 | 0.01 | -- |
| *Grindellia integrifolia* | 1.80 | 3.30 | 3.00 | 3.30 | 0.76 |
| *Holcus lanatus* | 0.55 | 0.22 | 0.07 | 0.11 | 0.04 |
| *Horkelia congesta* | 0.10 | -- | -- | -- | -- |
| *Hypericum perforatum* | 0.01 | 0.02 | 0.02 | 0.06 | 0.01 |
| *Hypochaeris radicata* | 11.80 | 15.20 | 21.60 | 18.90 | 19.46 |
| *Isoetes* sp. | -- | 0.03 | 0.01 | 0.05 | 0.05 |
| *Juncus bufonius* | 0.01 | 0.03 | 0.15 | 0.01 | 0.07 |
| *Juncus nevadensis* | 0.33 | 0.60 | 0.31 | 0.42 | 0.24 |
| *Juncus tenuis* | 1.90 | 0.71 | 1.25 | 1.65 | 1.15 |
| *Linum bienne* | -- | 0.03 | -- | -- | 0.01 |
| *Lotus formosissimus* | 0.36 | 1.05 | 0.82 | 0.71 | 0.06 |
| *Luzula* sp. | 0.12 | -- | 0.16 | 0.10 | 0.06 |
| *Mentha pulegium* | 5.27 | 5.00 | 7.30 | 9.15 | 15.51 |
| *Microseris laciniata* | 0.01 | 0.03 | 0.05 | 0.15 | 0.05 |

| | | | | | |
|---|---|---|---|---|---|
| *Montia* sp. | -- | 0.01 | -- | -- | -- |
| *Myosotis discolor* | 0.02 | 0.01 | 0.01 | -- | -- |
| *Orthocarpus* sp. | -- | -- | -- | 0.11 | -- |
| *Panicum scribnerianum* | 0.20 | 0.23 | 0.10 | -- | 0.40 |
| *Panicum* sp. | 0.20 | 0.01 | 0.20 | 0.10 | 0.80 |
| *Parentucellia viscosa* | -- | -- | 0.01 | 0.01 | 0.06 |
| *Perideridia oregana* | -- | 0.01 | -- | -- | -- |
| *Plagiobothrys* sp. | -- | -- | 0.01 | 0.30 | 0.01 |
| *Plantago lanceolata* | -- | -- | -- | 0.10 | -- |
| *Potentilla gracilis* | -- | 0.325 | 0.1 | -- | -- |
| *Prunella vulgaris* | 1.47 | 0.875 | 0.87 | 0.81 | 1.91 |
| *Prunus* sp. | -- | 0.01 | -- | -- | -- |
| *Rosa* sp. | 14.1 | 8.68 | 7.85 | 7.71 | 5.1 |
| *Rubus armeniacus* | 0 | 0.2 | 0 | 0.2 | 0.2 |
| *Senecio jacobea* | -- | 0.05 | -- | 0.2 | 0.01 |
| *Sherardia arvensis* | 1.1 | 0.05 | 0.05 | 0.25 | 0.07 |
| *Sisyrinchium angustifolium* | 0.06 | 0.05 | 0.04 | 0.02 | 0.02 |
| *Sisyrinchium idahoense* | 0.02 | 0.02 | 0.02 | 0.07 | 0.05 |
| *Vulpia* sp. | -- | 0.01 | 0.01 | 0.01 | -- |
| *Zigadenus venonosus* | 0.31 | 0.29 | 0.6 | 0.46 | 0.12 |

*Dashes indicate that a species was not present in the plots when monitored. A zero indicates the species was present, but at levels below the number of significant digits reported.