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

2016

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

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Institute for Applied Ecology

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PREFACE

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

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

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EXECUTIVE SUMMARY

Overall, several treatment(s) show promise for individual aspects that we were considering (*Anthoxanthum odoratum* cover, native species cover, and exotic species cover). Currently, no individual treatment tested provides desired levels of all of the measured variables. Future monitoring is necessary to continue to refine the management techniques and provide the most accurate recommendations.

Rose Prairie

In 2016, cover of *Anthoxanthum odoratum* ranged from 3% to 8%. Only the 2015 February glyphosate treatment had lower *A. odoratum* cover than the control treatment. Native cover ranged from 48% to 75%, and was significantly higher in control plots than in any of the treatments. Non-native exotic cover ranged from 11% to 31%, but no treatment effects were observed.

Native graminoid cover ranged from 29% to 66%, with the control plots having significantly higher cover than any of the treatments. Exotic graminoid cover ranged from 4% to 12%, but no treatment effects were observed. Native forb cover ranged from 7% to 19%, with the control treatment significantly lower than all other treatments except for the 2015 February glyphosate treatment. Exotic forb cover ranged from 4% to 25%, and was significantly higher in the burn + fusilade treatment when compared to the control treatment.

Fisher Butte

In 2016, *Anthoxanthum odoratum* cover ranged from 2% to 12% and varied among treatments. The control (11%) and burn + glyphosate treatment (12%) had the highest *Anthoxanthum* cover while the burn + 2 applications of fusilade (1%) and the 2015 February glyphosate treatment (2%) had the least *Anthoxanthum* cover.

Native cover ranged from 22% to 59% and varied significantly among treatments. Control plots had the highest native cover (59%) and the 2015 February glyphosate treatment had the least native cover (22%). Exotic cover did not vary among treatments.

Native graminoid cover ranged from 8% to 54%, with significantly higher cover in the control plots. All herbicide treatments reduced native graminoid cover to below 20%, with the 2015 February glyphosate treatment reducing cover the most (8%). Exotic graminoid cover ranged from 3% to 26% and varied significantly among treatments. The burn + 2 applications of fusilade and the 2015 February glyphosate treatment had the lowest exotic graminoid cover (3% and 4%, respectively).

Native forb cover ranged from 5% to 21% and varied significantly among treatments. The control had the least native forb cover (5%), while the burn + one application of glyphosate had the highest native forb cover (21%). Exotic forb cover ranged from 19% to 52% and varied significantly among treatments. The burn + 2 applications of fusilade had the highest exotic forb cover (52%), followed by the burn + 1 application of fusilade (48%).

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 BRASHAWII (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, *personal communication*), in Wetland Restoration Enhancement Program sites (M. Blakeley-Smith, *personal communication*), and upland prairies in the Willamette Valley and Puget Trough (Boyer 2008; Stanley et al. 2008; Stanley et al. 2010). 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 + Glyphoste (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.). Each year, IAE staff will consult with Corps specialists and decide if additional treatments are necessary.

Experimental design and data collection

Rose Prairie

In 2010, five blocks were established at Rose Prairie (Figure 3, 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. Percentage 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 as planned due to standing water at the site. Thus, treatments 4 and 5 were functionally the same (burn plus one fusilade treatment) and combined for analysis. Post-treatment vegetation monitoring has been conducted in late May/early June of 2012 and 2015. A follow-up application of fusilade was applied to treatment 4 in February 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.

Fisher Butte

In 2011, five blocks were established at Fisher Butte (Appendix B). Treatments were randomly assigned to plots within each block (Appendix B.). 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 1m^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 1m^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 (see Appendix B.). Thus, treatments 2 and 3 (Appendix B.) were functionally the same (burn plus one glyphosate treatment) and combined for analysis. Post-treatment vegetation monitoring was conducted in late May 2015.

Statistical Analysis

Analysis of Variance (ANOVA) procedures, using R (R Core Team 2014), were conducted 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

The fall 2011 fire at Rose Prairie was patchy. The highest temperatures in each plot were generally between 225°C – 575°C. In a few plots, the temperature exceeded 575°C, but was less than 750°C. Thus, all plots represent a combination of the various intensities of the burns. In pre-treatment monitoring at Rose Prairie, we found 42 vascular plant species (Appendices C, E), 43 species post-treatment in 2012 (Bois 2012), 40 species in 2015 and 42 species in 2016. In addition to the total richness remaining stable, there were no significant differences in the average species richness among the various treatment plots in 2016 (p=0.4028).

Anthoxanthum odoratum

In 2012, cover of *Anthoxanthum odoratum*, our key target invader, ranged from a mean cover of 5% to 12%, with variation among treatments (Bois 2012), while in 2016 it ranged from 3% to 8% with no variation among treatments (p=0.369; Figure 6). The burn + 2 applications of glyphosate treatment had the highest mean *Anthoxanthum* cover, although there was overlap among the treatment means.

Nativity

In 2012, mean native cover did not differ among plots (Bois 2012), but did vary significantly in 2016 (p=0.0589; Figure 7). Native cover ranged from 48% to 75%, and was significantly higher in control plots than in any of the treatments (Figure 7). The burn + 1application of glyphosate had the highest native cover of any of the treated plots, although there was overlap among the treatment means.

In 2016, mean exotic cover ranged from 11% to 31%, but only slight differences were observed between the control and treated plots (p=0.0601; Figure 7). The burn + 1 application of fusilade had the highest cover of any of the treated plots, and the burn + 1 application of glyphosate had the least exotic cover of any of the treated plots, although there was overlap among the treatment means (Figure 7).

Graminoid Cover

In 2016, mean native graminoid cover ranged from 29% to 66%, with control plots having significantly higher cover than any of the treatments (p=<0.0001; Figure 8). Among the treatments, there was no difference in mean native graminoid cover (Figure 8).

In 2016, exotic graminoid cover ranged from 4% to 12%, but no differences were observed between the control and treated plots. The 2015 February glyphosate treatment had the lowest cover of the treatments, although there was overlap in the treatment means (Figure 8).

Forb Cover

In 2016, mean native forb cover ranged from 7% to 19%, and varied among treatments (p=0.0163). The control was significantly lower than all treatments except the 2015 February glyphosate treatment (Figure 9). The burn + 1 application of glyphosate and burn + 2 applications of glyphosate treatments had the highest cover of native forbs, although there was overlap in native forb cover among treatments (Figure 9).

In 2016, mean exotic forb cover ranged from 4% to 25%, and varied among treatments (p=0.0163; Figure 9). The control treatment was significantly lower than the burn + 1 application of fusilade treatment. The burn + 1 application of glyphosate treatment significantly reduced mean exotic forb cover more than the burn +1 application of fusilade and the 2015 February glyphosate treatments.

Substrate

In 2016, cover of bare ground and litter was variable across plots, although only litter (p=0.0004; Figure 10) varied significantly between treatments. Mean bare ground cover was highest in the burn + 1 application of glyphosate and the 2015 February glyphosate treatments (Figure 10). Litter was highest in the control treatment and lower in the treatments with higher bare ground cover (Figure 10).

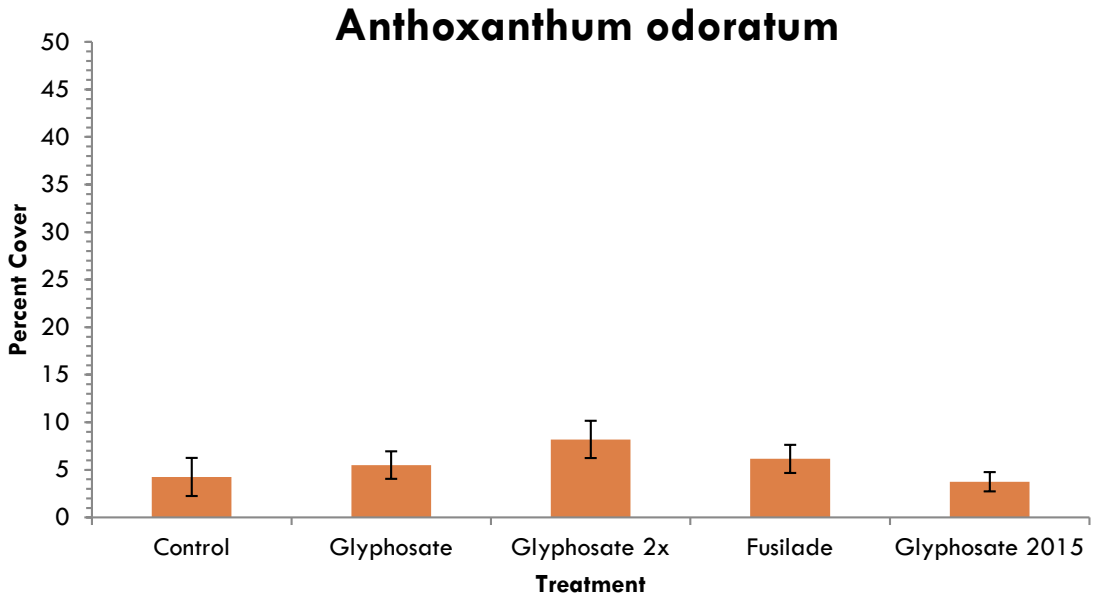

FIGURE 5. *ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2016. *NOTE SCALE WITH MAXIMUM OF 50%. NO SIGNIFICANT DIFFERENCES WERE FOUND.

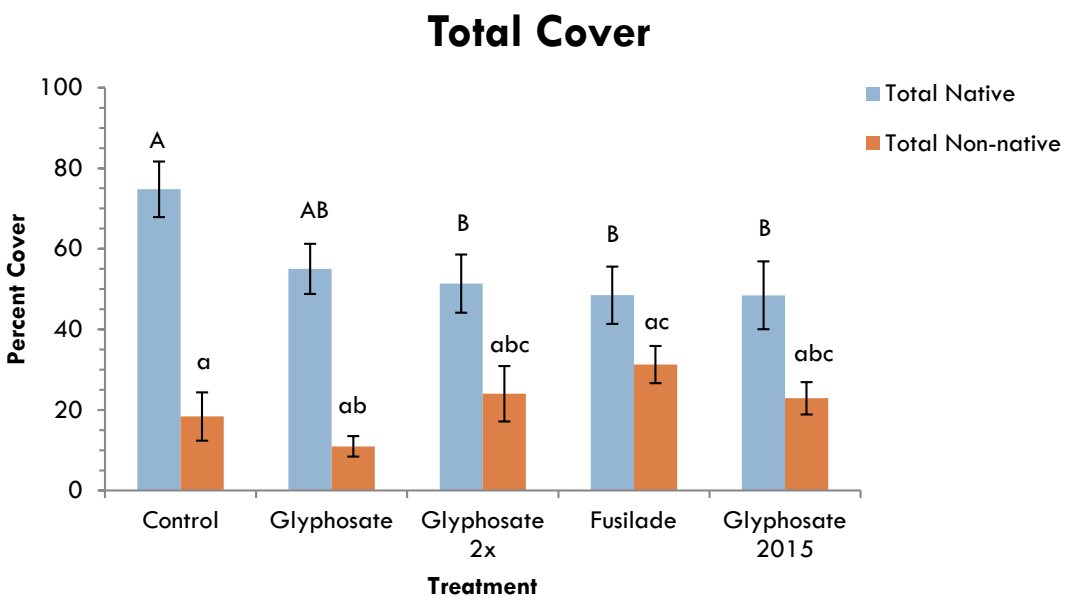

FIGURE 6. TOTAL NATIVE AND NON-NATIVE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE COVER AMONG TREATMENTS. LOWERCASE LETTERS ABOVE RED BARS INDICATE DIFFERECNES IN TOTAL NON-NATIVE COVER AMONG TRETMENTS.

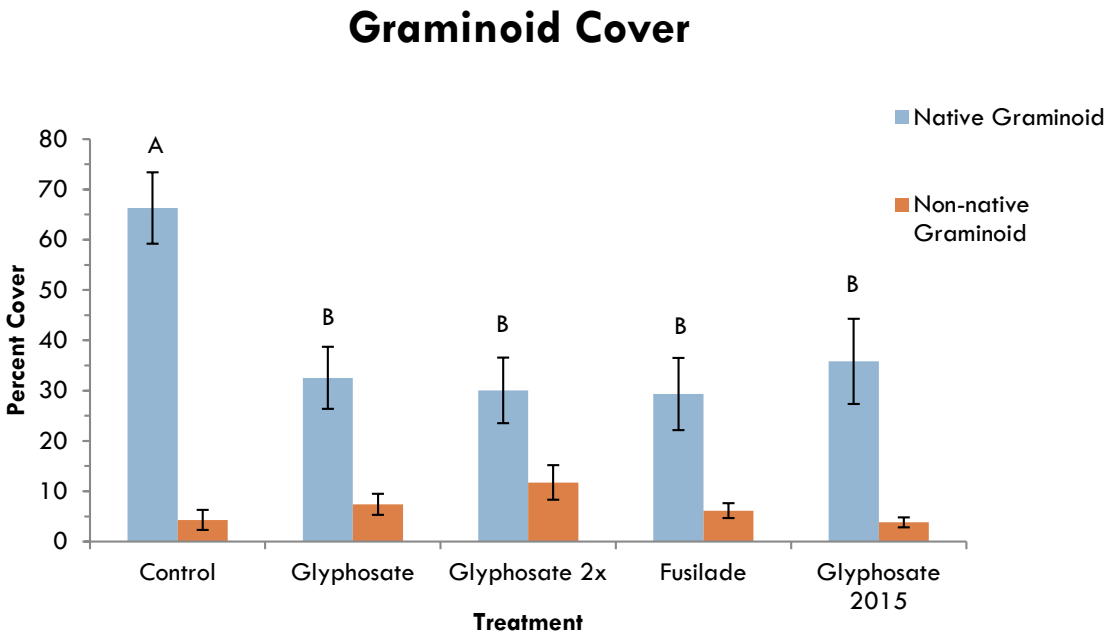

FIGURE 7. NATIVE AND EXOTIC GRAMINOID COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE GRAMINOID COVER AMONG TREATMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND.

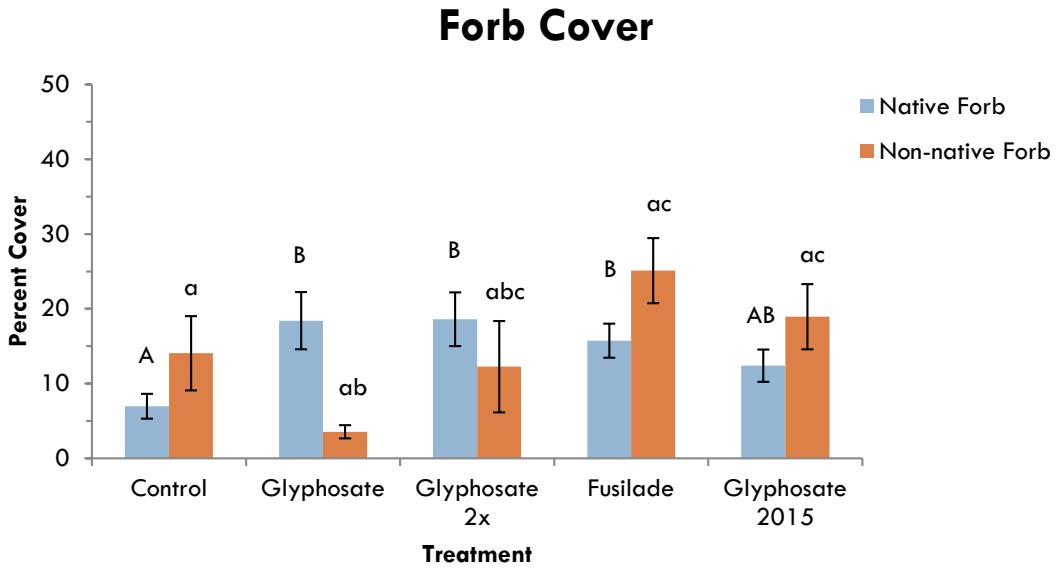

FIGURE 8. NATIVE AND EXOTIC FORB COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE FORB COVER AMONG TREATMENTS. LOWERCASE LETTERS ABOVE RED BARS INDICATE DIFFERECNES IN TOTAL NON-NATIVE FORB COVER AMONG TRETMENTS.*NOTE SCALE WITH MAXIMUM OF 50%.

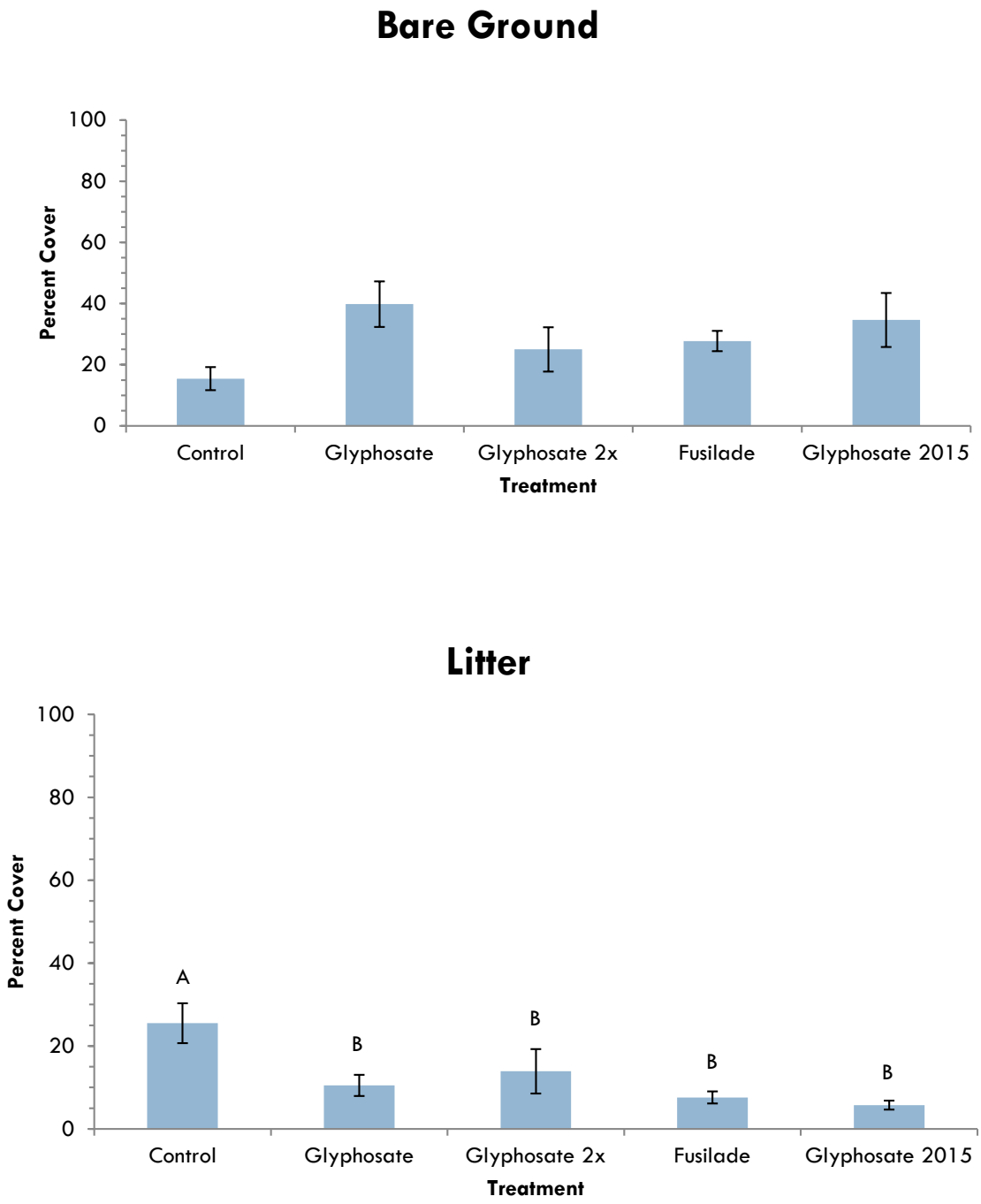

FIGURE 9. SUBSTRATE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2016. UPPERCASE LETTERS ABOVE BARS INDICATE DIFFERECNES IN TOTAL LITTER COVER AMONG TRETMENTS. NO SIGNIFICANT DIFFERENCES WERE FOUND FOR BARE GROUND.

Fisher Butte

The fall 2014 fire at Fisher Butte was varied in highest temperature recorded on our fire tags. The highest temperatures in each plot were generally between 225°C – 575°C. In a few plots, the temperature exceeded 575°C, but was less than 750°C. Thus, all plots represent a combination of the various intensities of the burns. We found 52 vascular plant species pre-treatment in 2014 (Appendix F) and 44 species post-treatment in 2016. There was a significant difference in the average species richness among the various treatments (p=0.0037) in 2016, with the 2015 February glyphosate treatment reducing average species richness the most among treatments.

Anthoxanthum odoratum

In 2014, pretreatment cover of *Anthoxanthum odoratum,* our key target invader, ranged from 15% to 35% (Appendix G). In 2016, cover of *Anthoxanthum* ranged from <2% to12% and varied among treatments (p=0.010; Figure 11). The burn + 1 application of glyphosate had the highest *Anthoxanthum* cover (12%), and the burn +2 applications of fusilade (<2%) and the 2015 February glyphosate (2%) treatments had the least *Anthoxanthum* cover.

Nativity

In 2016, native cover ranged from 22% to 59% and varied significantly between treatments (p=<0.0001; Figure 12). The control had the highest native cover and all herbicide treatments reduced native cover less than the control, although there was overlap in mean differences between treatments (Figure 12). There was no difference in exotic cover (p=0.1168; Figure 12) between the treatments in 2016.

Graminoid Cover

In 2016, native graminoid cover ranged from 8% to 54%, with significantly higher cover in the control plots (p=<0.0001; Figure 13). The 2015 February glyphosate treatment reduced native graminoid cover significantly more than the burn + 1 application of fusilade, and there was no difference in native graminoid cover between the other treatments (Figure 13).

In 2016, exotic graminoid cover ranged from 4% to 26% and varied significantly among treatments (p<0.0026; Figure 13). The burn + 2 applications of fusilade and the 2015 February glyphosate treatments had significantly less exotic graminoid cover than the burn + 1 application of glyphosate treatment (Figure 13).

Forb Cover

In 2016, native forb cover ranged from 5% to 21% (Figure 14) and varied significantly among treatments (p<0.0043). The burn + 1 application of glyphosate had significantly higher native forb cover than the control and burn +1 application of fusilade treatments.

In 2016, exotic forb cover ranged from 19% to 52% (Figure 14) and varied significantly among treatments (p<0.0001). Both fusilade treatments and the 2015 February glyphosate treatment had significantly higher exotic forb cover than the control and burn + 1 application of glyphosate treatments (Figure 14).

Substrate

In 2016, bare ground cover ranged from 20% to 41%, but there was no difference between treatments (p=0.131; Figure 15). Litter cover ranged from 5% to 9% and no differences were observed between treatments (p=0.1343; Figure 15).

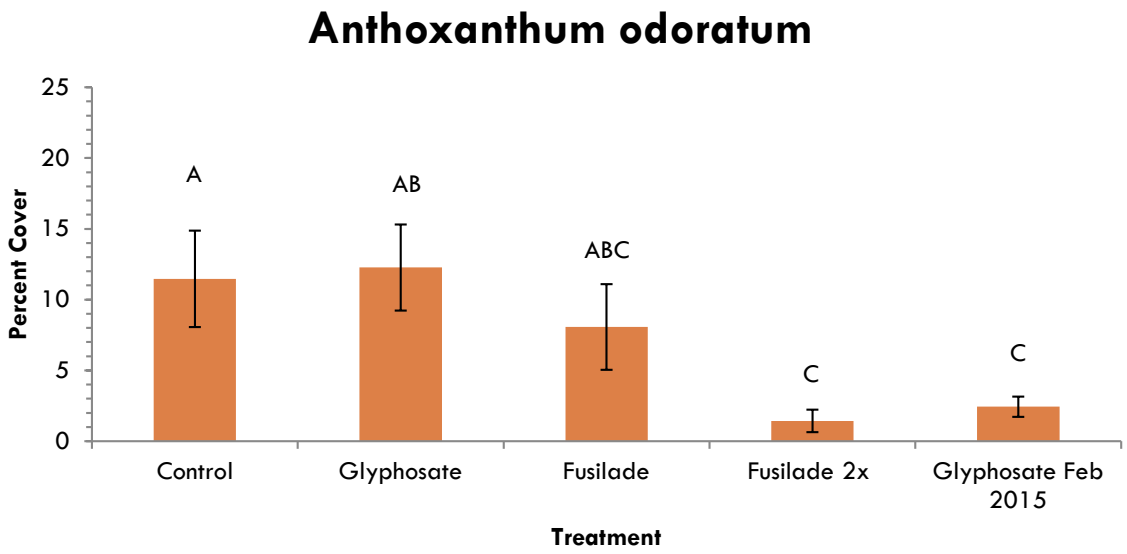

FIGURE 10. ***ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT FISHER BUTTE IN 2016. UPPERCASE LETTERS ABOVE BARS INDICATE DIFFERECNES IN TOTAL ANTHOXANTHUM ODORATUM COVER AMONG TRETMENTS. *NOTE SCALE WITH MAXIMUM OF 25%.**

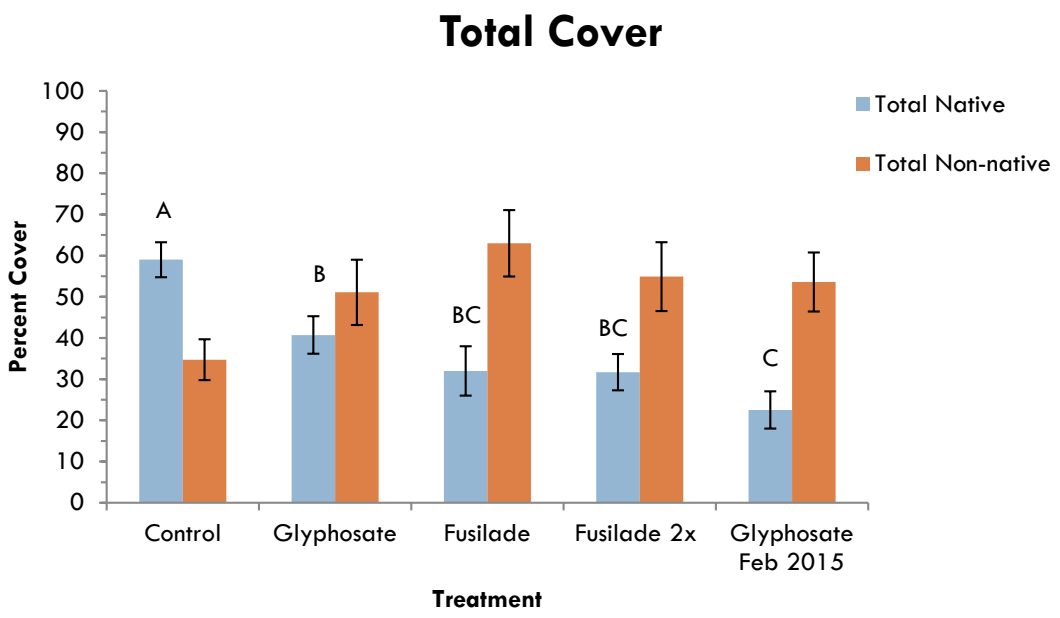

FIGURE 11. TOTAL NATIVE AND NON-NATIVE PLANT COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERECNES IN TOTAL NATIVE COVER AMONG TRETMENTS. NO SIGNIFICANT DIFFERENCES BETWEEN TREATMENTS WERE FOUND IN NON-NATIVE COVER.

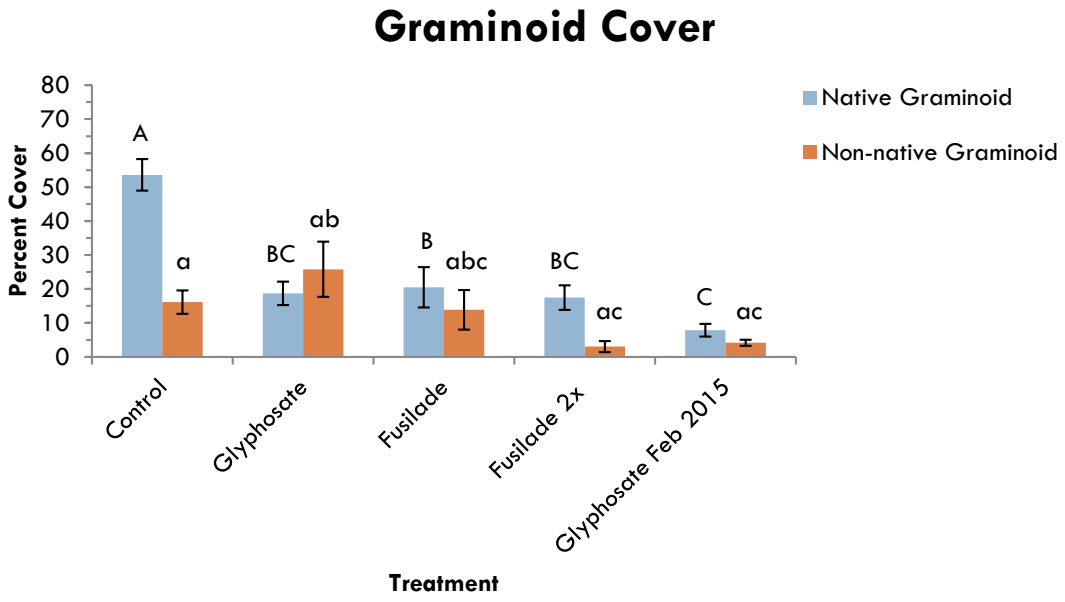

FIGURE 12. NATIVE AND EXOTIC GRAMINOID COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE GRAMIMOID COVER AMONG TREATMENTS. LOWERCASE LETTERS ABOVE RED BARS INDICATE DIFFERECNES IN TOTAL NON-NATIVE GRAMINOID COVER AMONG TRETMENTS. *NOTE SCALE WITH MAXIMUM OF 80%.

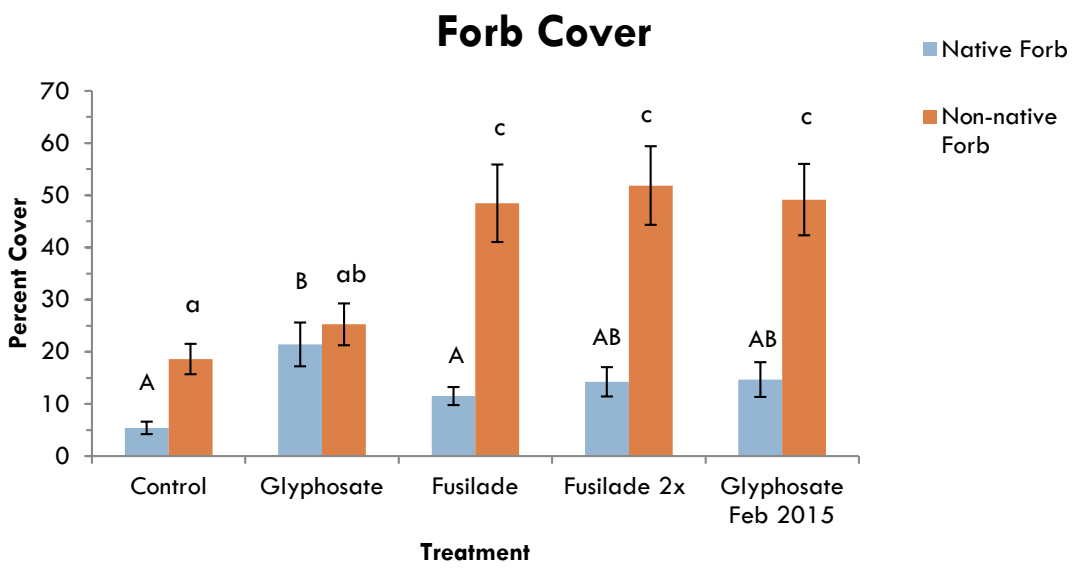

FIGURE 13. NATIVE AND EXOTIC FORB COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2016. UPPERCASE LETTERS ABOVE BLUE BARS INDICATE DIFFERNCES IN TOTAL NATIVE FORB COVER AMONG TREATMENTS. LOWERCASE LETTERS ABOVE RED BARS INDICATE DIFFERECNES IN TOTAL NON-NATIVE FORB COVER AMONG TRETMENTS. *NOTE SCALE WITH MAXIMUM OF 70%.

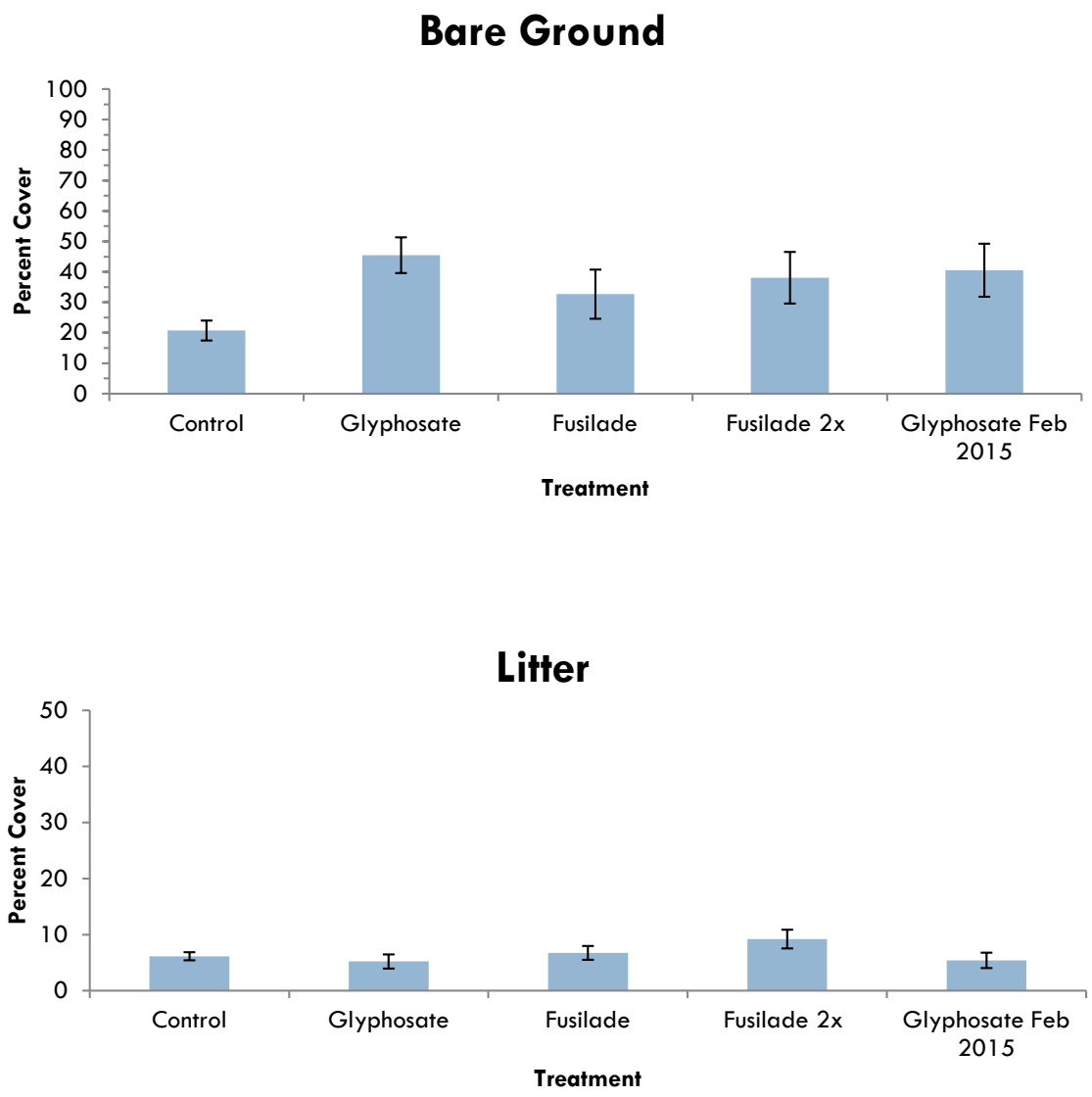

FIGURE 14. **SUBSTRATE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2016. *NOTE LITTER SCALE WITH MAXIMUM OF 50%. NO SIGNIFICANT DIFFERENCES WERE FOUND.**

DISCUSSION

Rose Prairie and Fisher Butte are relatively high quality wetland prairies, with a moderately diverse native plant community and few exotic species. However, aggressive, fire-tolerant, exotic grasses pose a large risk to remnant wetland prairies. We found *Anthoxanthum odoratum* is present at both Rose Prairie and Fisher Butte, and total exotic cover is relatively high. Finding efficient management strategies to reduce exotic grasses while minimizing non-target effects is essential to maintain and improve the quality of wetland prairies over the long term. Overall, there are treatment(s) that show potential for reducing *Anthoxanthum* cover, increasing native cover, and reducing overall exotic plant cover. Future monitoring is necessary to continue to monitor the response of the plant communities to develop the most effective management strategy or strategies.

Rose Prairie

In 2015, herbicide treatments reduced *Anthoxanthum* cover significantly, but in 2016, herbicide treatments had no effect on *Anthoxanthum* cover. Additionally, there was approximately 25% more *Anthoxanthum* cover in the control plots in 2015 than 2016. Differences in *Anthoxanthum* cover between 2015 and 2016 may reflect annual *Anthoxanthum* population fluctuations (Antonovics 1972). Future monitoring is recommended to better understand how herbicide impacts *Anthoxanthum* cover.

From 2015 to 2016, cover of native graminoids increased greatly in control plots and cover of exotic graminoids decreased. *Anthoxanthum* cover was significantly lower in the control plots in 2016, potentially opening up niche space for native grasses to become established. For example, *Deschampsia caespitosa*, a native bunch grass, doubled in cover across control plots from 2015 to 2016. All 2016 treated plots followed similar trends of relatively high native graminoid cover compared to low exotic graminoid cover, suggesting a shift in graminoid community composition from relatively equal native and exotic graminoid cover, as observed in 2015, to a graminoid community dominated by natives. Future monitoring will provide additional information on how graminoid communities respond to treatments, and suggestions on future efforts can be made.

In 2016, native forbs did not experience detrimental impacts to herbicide treatments as previously observed. An increase in native forb cover across all treatments between 2015 and 2016 suggests a strong recovery from the initial herbicide application. Exotic forbs followed similar trends as 2015, with the glyphosate treatment having relatively low exotic forb cover, however, timing of glyphosate application is critical to minimize damage to non-target species (Tesfamariam et al. 2009). Future monitoring will provide additional information on forb community response to the treatments, and suggestions on future efforts can be made.

Future monitoring will provide information on plant community responses to the treatments, and suggestions on future efforts can be made. For 2017, we do not recommend any additional treatments.

Fisher Butte

Similar trends in *Anthoxanthum odoratum* cover were observed from 2015 to 2016, except for the burn + 1 application of glyphosate. For this treatment, *Anthoxanthum* cover increased during the 2015/2016 year. In the short term, glyphosate may reduce *Anthoxanthum* cover, but *Anthoxanthum* cover appears to recover quickly from the initial glyphosate application. Contrary to the burn + 1 application of glyphosate treatment, the burn + 2 applications of fusilade kept *Anthoxanthum* cover below 2% in both years. Fusilade is a more resilient herbicide compared to glyphosate (i.e, persists in the soil longer), meaning residuals from the herbicide application may continue to impact *Anthoxanthum* cover long after initial application. Future monitoring will provide additional information on how *Anthoxanthum* responds to the treatments, and suggestions on future efforts can be made.

In 2016, graminoid cover showed a similar pattern, regardless of nativity in all treatments except in the control and the burn + 2 applications of fusilade treatment. As aforementioned, fusilade is more resilient compared to glyphosate, and therefore, appears to be more effective at reducing exotic graminoids, although non-target species were also reduced by this treatment. The control had the highest native graminoid cover with moderate exotic cover. In addition, mean native cover in control plots increased from 2015 to 2016. None of the treatments provide a recommended alternative at this time and future monitoring will determine the best method(s) for future efforts.

Native and exotic forb responses varied across treatments. Forb cover from 2015 to 2016 doubled in the burn + 1 application of glyphosate treatment for both natives and exotics. This may reflect the short term effect of glyphosate and the resilience of forbs to recover from glyphosate application. Exotic forb cover was significantly higher in both fusilade treatments. This may be a negative response from the decrease in exotic grasses from these treatments. The increase in forb cover was dominated by *Hypochaeris radiata*. This species may require future control efforts, but we suggest continued monitoring in 2017 prior to suggesting control efforts that may be detrimental to native forb community.

Future monitoring will provide information on plant community responses to the treatments, and suggestions on future efforts can be made. For 2017, we do not recommend any additional treatments.

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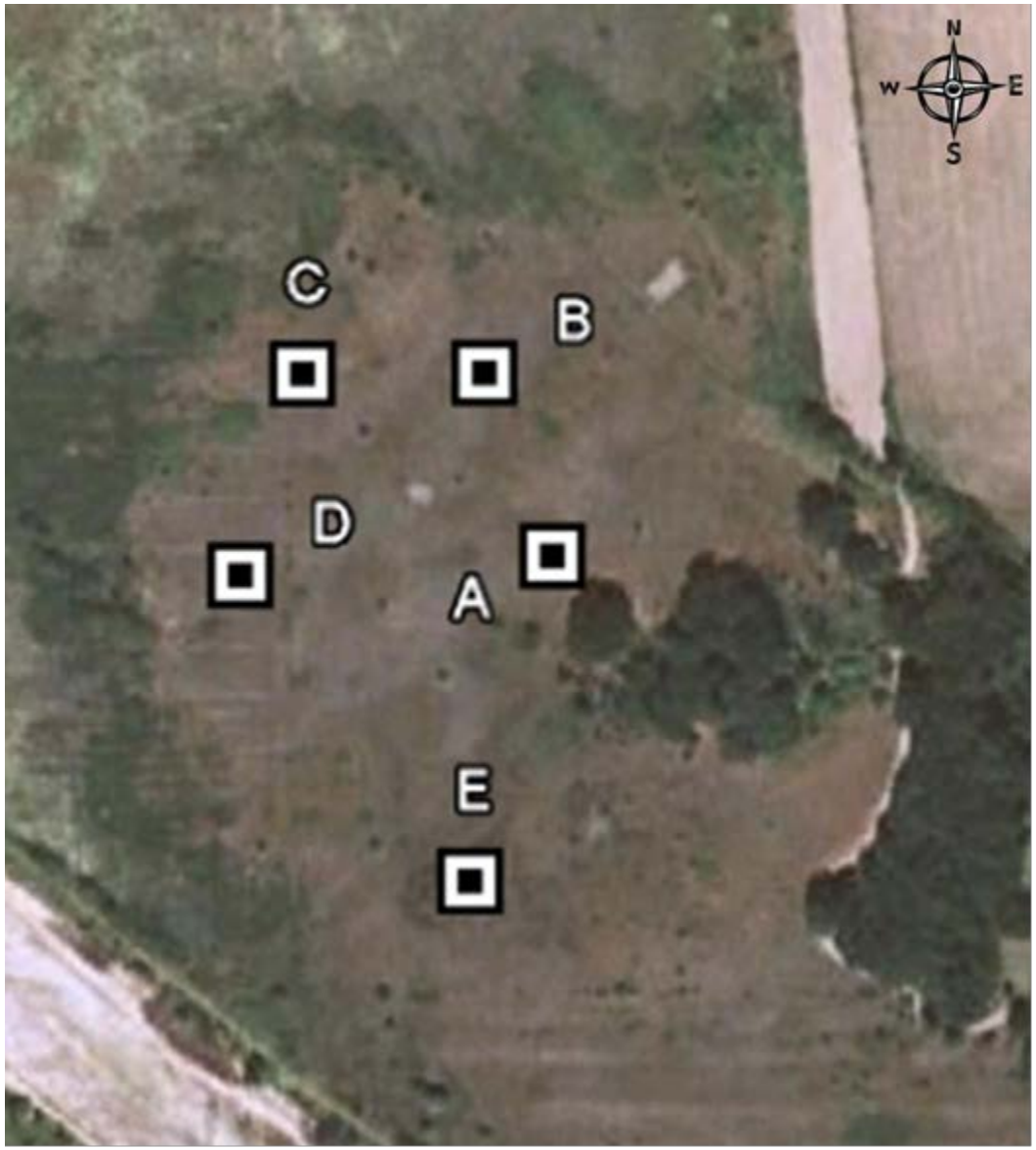
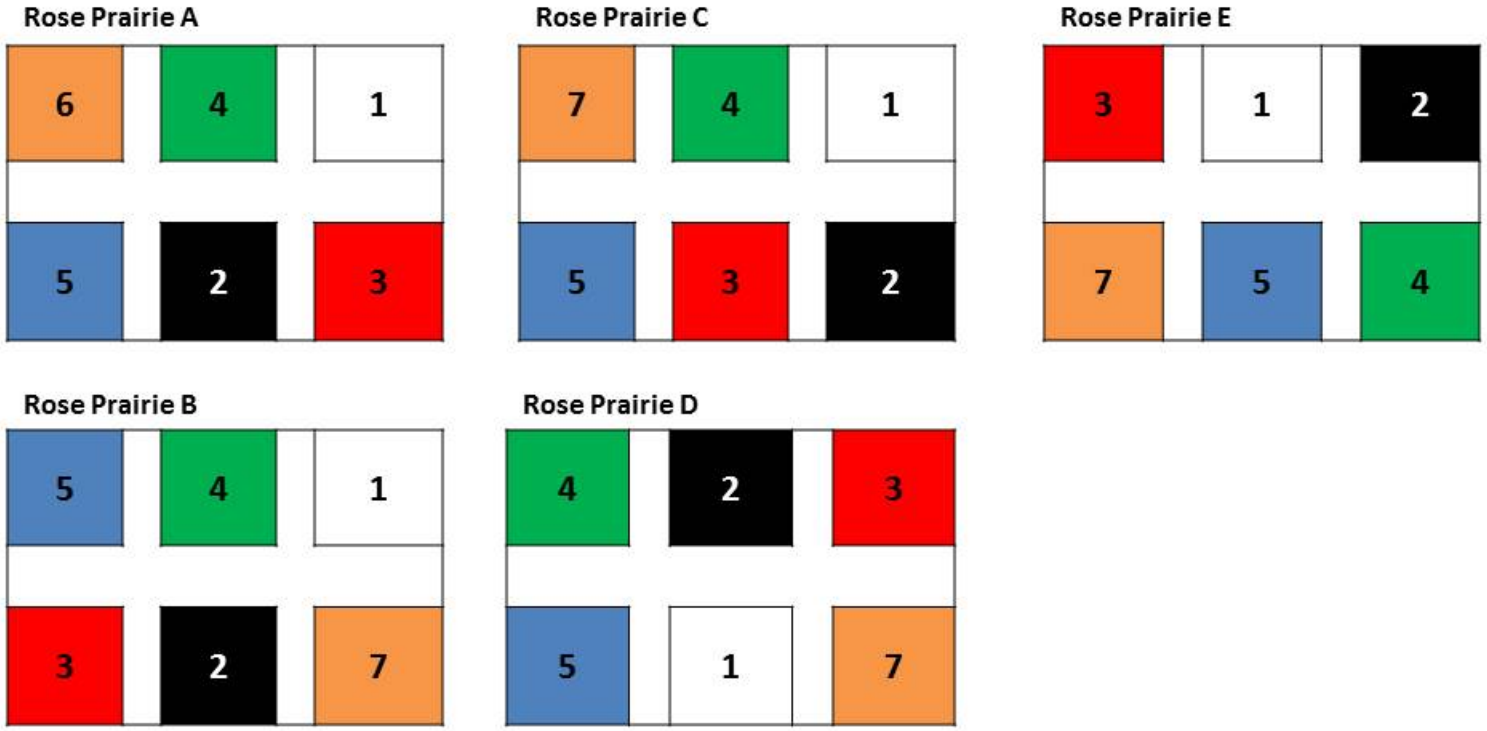
APPENDIX A. ROSE PRAIRIE MAP, PLOT LOCATIONS, AND TREATMENT ASSIGNMENTS



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.

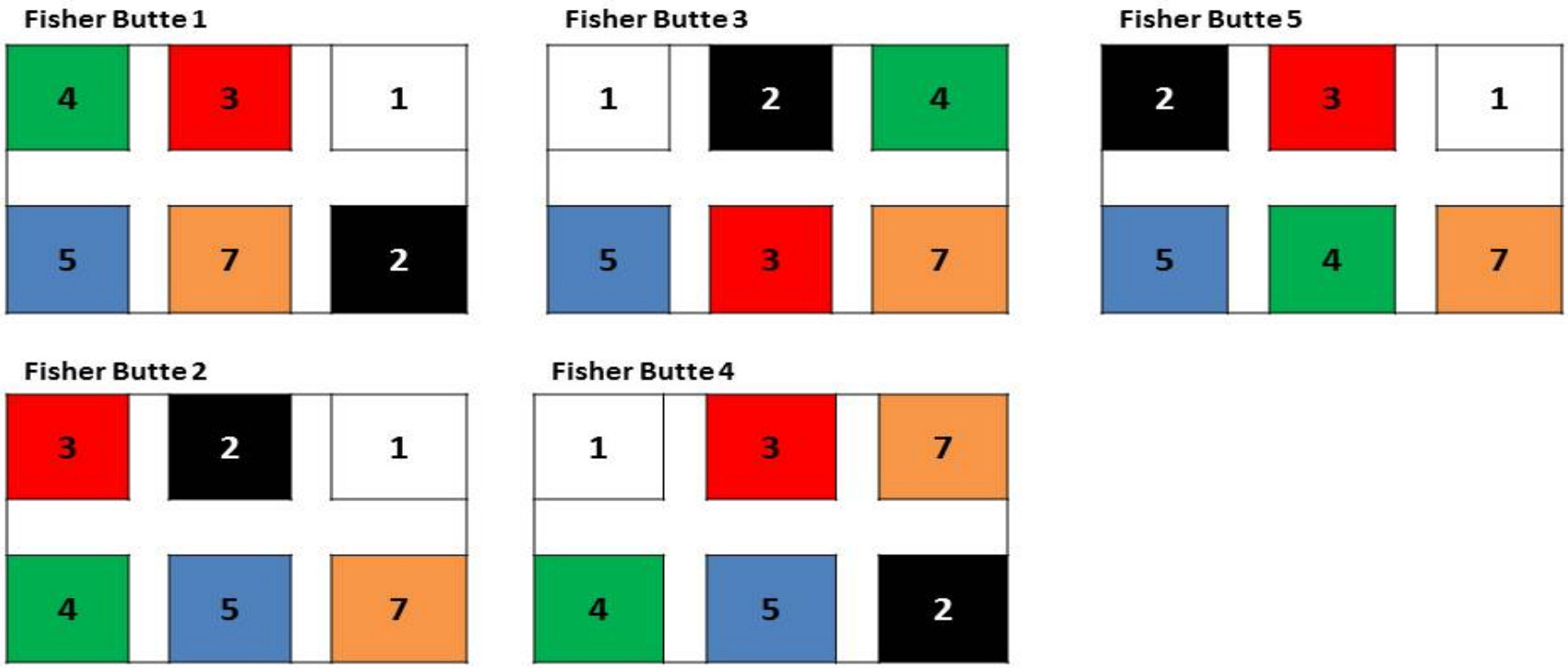
Plot	Coordinates (WGS 84)	
A	44.08658260	-123.24841065
B	44.08724444	-123.24875331
C	44.08724142	-123.24967104
D	44.08651228	-123.24998427
E	44.08540637	-123.24882522



Treatments

1	Control
2	Glyphosate 1-2 weeks post-fire
3	Glyphosate 1-2 weeks post fire & February glyphosate
4	Fusilade 1-2 weeks post-fire
5	Fusilade 1-2 weeks post fire & Fusilade Feb. 2015 (Plot A not sprayed due to standing water)
6	Sufactant Only (Removed from analysis due to only having single sample)
7	Glyphosate Feb. 2015 (Inadvertantly 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 & February glyphosate
4	Fusilade 1-2 weeks post-fire
5	Fusilade 1-2 weeks post fire & Fusilade Feb. 2015 (Plot A not sprayed due to standing water)
6	Sufactant Only (See Below)
7	Glyphosate Feb. 2015 (Inadvertantly 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 quammash	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 douglassii	--	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
Grindellia 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 bufonis	--	0.5	0.92	0.5	0.42
Juncus ssp.	--	--	0.5	--	--
Juncus tenuis	0.05	0.12	0	0.08	0.08
Junucs 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 unifoliatus	--	--	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 figures reported.

APPENDIX D. AVERAGE COVER OF ALL SPECIES OBSERVED IN TREATED PLOTS AT ROSE PRAIRIE IN 2016.

	Treatment				
Species	**Control**	**Glyphosate**	**Glyphosate 2X**	**Fusilade**	**2015 Glyphosate**
Agrostis spp.	--	0.10	0.05	--	0
Allium acuminatum	--	0	--	0	--
Anthoxanthum odoratum	4.25	5.50	8.20	6.15	3.00
Aster curtus	0.70	--	--	--	--
Aster hallii	0	0	0.	0.08	0.10
Briza minor	0.05	1.80	3.50	0	0.05
Brodiaea hyacinthina	0.10	0.25	--	0.60	0
Camassia quammash	2.55	3.35	3.05	3.65	2.05
Centaurea pratensis	--	--	--	0.48	0.20
Crataegus douglassii	0	--	0	--	--
Danthonia californica	0.40	--	--	0.20	0.10
Deschampsia caespitosa	57.30	6.55	8.40	12.05	19.30
Epilobium sp.	--	--	0.10	--	--
Eriophyllum lanatum	0.40	8.08	5.55	3.23	1.25
Fragaria virginiana	0	--	--	--	--
Gratiola ebracteata	0	0.25	0	0.40	0.05
Grindellia integrifolia	0.80	2.20	6.30	2.80	5.75
Horkelia congesta	--	0	--	--	--
Hypericum perforatum	--	--	0.05	0	0
Hypochaeris radicata	13.15	3.50	9.80	23.70	15.40
Juncus bufonis	5.05	13.60	16.50	7.23	9.10
Juncus nevadensis	0.40	--	--	0.15	--
Juncus tenuis	1.05	11.90	3.15	3.55	1.80
Lomatium bradshawii	0	--	--	0.1	--
Lotus formosissimus	0.10	0.30	0.90	0.38	0.30
Luzula campestris	--	0.40	--	--	0.10
Mentha pulegium	0.40	--	0.50	--	--
Microseris laciniata	0.65	1.25	0.35	0.60	0.70
Myosotis discolor	0	0	0	--	0
Panicum occidentale	2.10	0.10	2.00	2.95	12.85

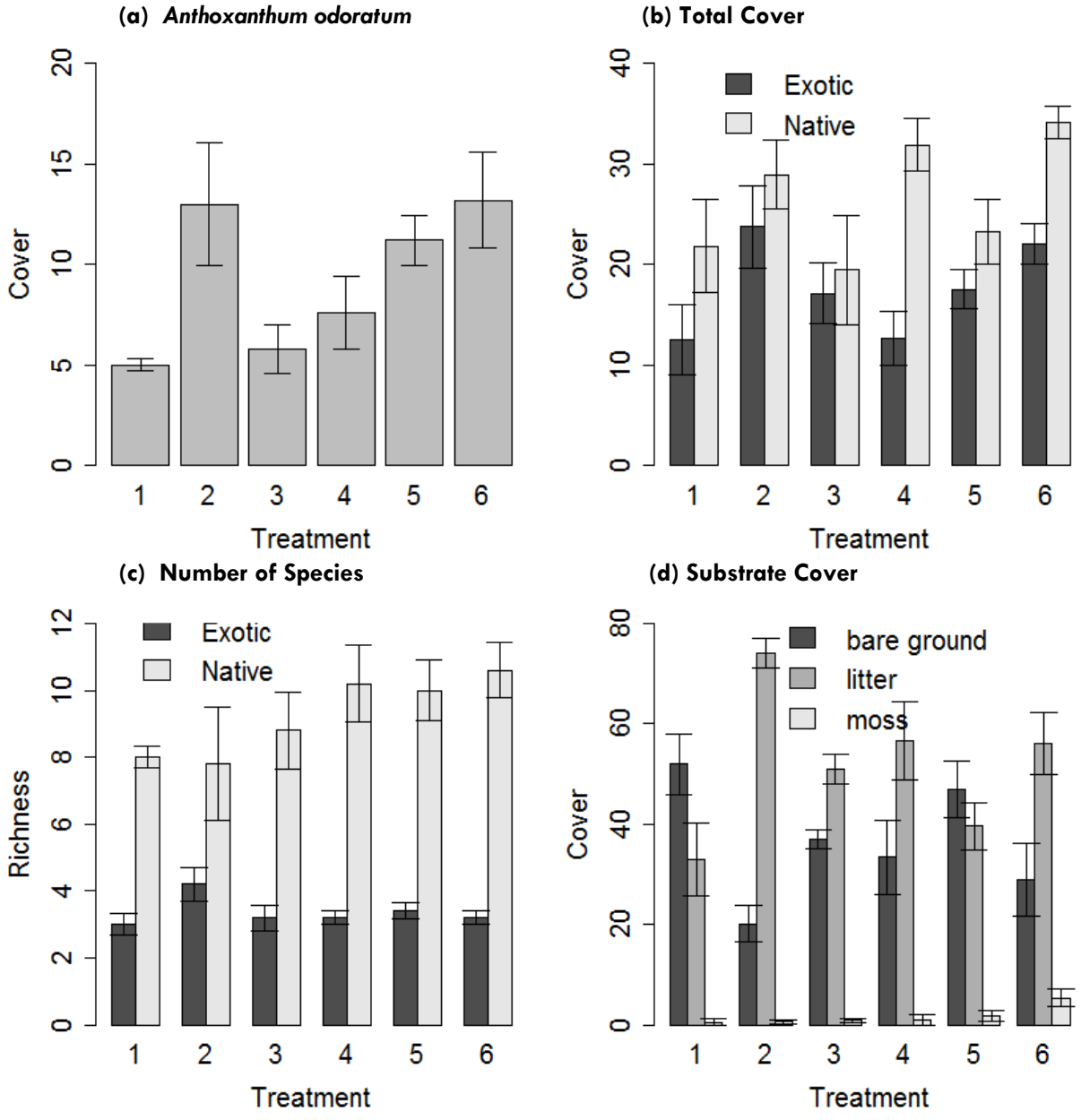
Plantago lanceolata	0.50	--	1.10	0.45	0.40
Prunella vulgaris	0.30	--	--	0.70	--
Rosa sp.	3.80	2.60	--	2.85	0.20
Rubus armeniacus	--	--	--	--	0.10
Rumex acetosella	--	--	0.05	--	0
Sherardia arvensis	0	0	0.75	0.03	0.45
Sisyrinchium angustifolium	0	0.15	0.35	1.40	0.40
Solidago spp.	1.30	0.70	0.70	2.15	1.20
Toxicodendron diversilobum	--	0.05	--	--	--
Vaccinium caespitosum	1.50	4.00	2.70	3.40	0.20
Viola odorata	--	--	--	0.30	--
Zigadenus venonosus	--	0.05	--	0.08	--

*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 figures 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	23.61	15.44	14.28	29.78	21.83
Litter	36.11	33.06	36.39	26.11	45.28
Moss	1.39	3.33	1.61	3.50	0.00

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.



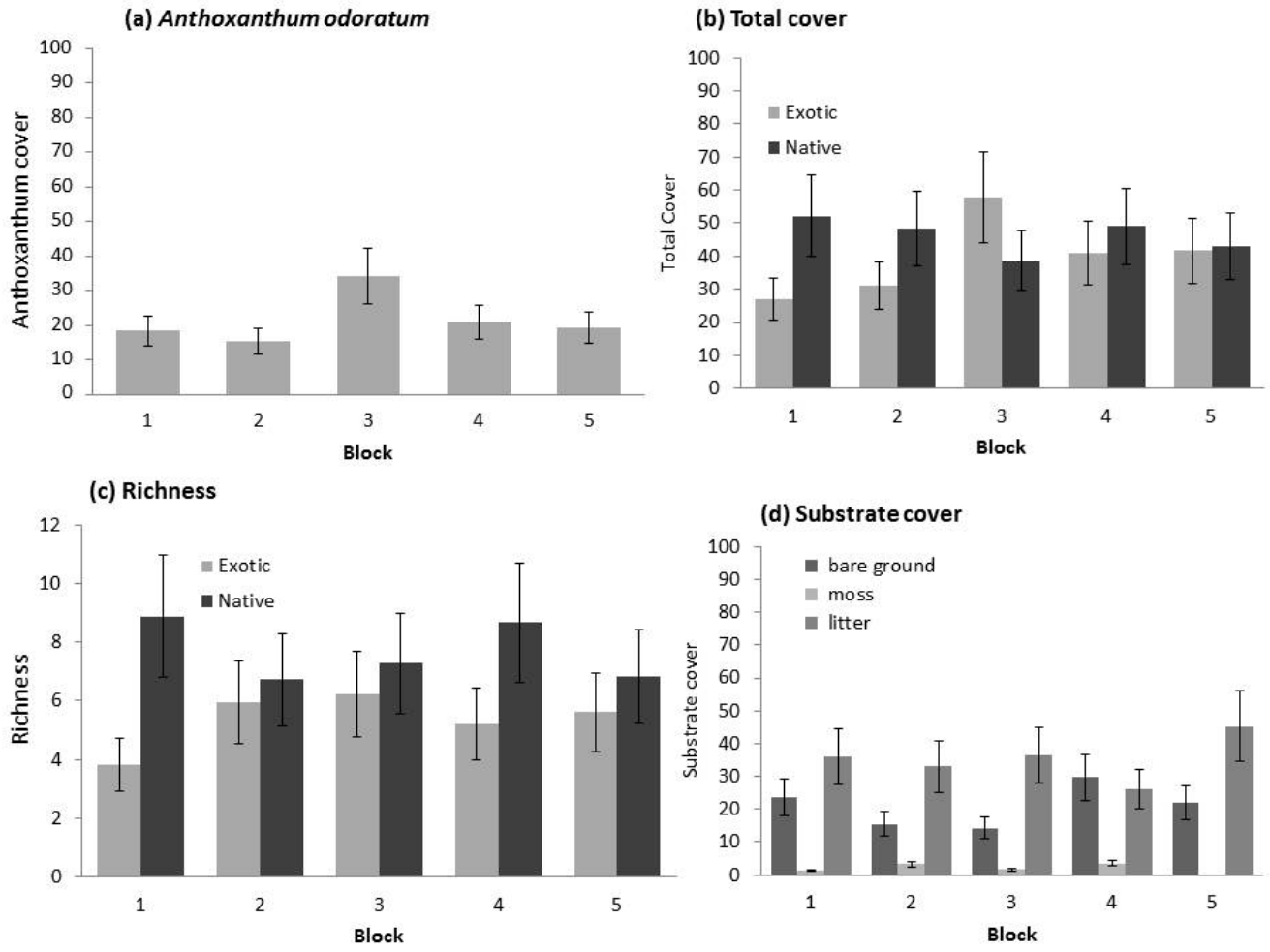
APPENDIX G. AVERAGE COVER OF ALL SPECIES OBSERVED IN PRE-TREATMENT MONITORING PLOTS AT FISHER BUTTE IN 2014.

	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 amplectans	--	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 quammash	--	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 douglassii	--	--	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	--
Grindellia 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 jacobea	--	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 venonosus	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 figures 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 TREATED PLOTS AT FISHER BUTTE IN 2016.

	Treatment				
Species	**Control**	**Glyphosate**	**Fusilade**	**Fusilade 2X**	**2015 Glyphosate**
Agoseris grandiflora	--	0.18	0.00	0.37	--
Agrostis spp.	--	--	--	--	0.00
Aira caryophyllea	--	--	0.67	--	--
Allium acuminatum	0.00	1.22	0.00	0.00	--
Anthoxanthum odoratum	11.47	12.27	8.07	1.43	2.43
Aster hallii	--	0.00	--	0.13	--
Briza minor	4.34	12.68	4.73	1.43	1.40
Brodiaea hyacinthina	1.67	7.23	3.00	3.63	2.03
Bromus hordeaceus	0.03	0.10	--	--	--
Camassia quammash	0.83	1.60	0.33	0.43	0.63
Centaurea pratensis	--	0.07	0.10	--	--
Crataegus douglassii	--	0.02	--	--	--
Danthonia californica	0.53	--	--	--	--
Deschampsia caespitosa	43.87	4.40	2.57	0.20	2.50
Epilobium sp.	0.53	0.12	0.03	--	0.03
Erigeron decumbens	--	0.28	0.10	0.07	--
Eriophyllum lanatum	0.20	1.93	0.03	1.67	0.13
Festuca arundinacea	--	0.07	--	--	--
Fraxinus	--	0.60	--	--	--
Gratiola ebracteata	0.00	0.02	0.00	--	--
Grindellia integrifolia	0.77	5.43	3.10	4.73	10.07
Holcus lanatus	0.30	0.52	0.40	0.17	0.33
Horkelia congesta	--	--	--	--	0.17
Hypericum perforatum	0.00	0.07	0.57	0.30	--
Hypochaeris radicata	9.17	8.18	26.03	29.17	19.07
Juncus bufonis	0.27	0.35	0.53	0.53	1.50
Juncus tenuis	8.93	13.97	17.40	16.73	3.87
Lomatium bradshawii	--	--	--	--	0.03
Lotus formosissimus	0.00	0.37	0.27	0.00	0.10
Mentha pulegium	9.40	16.87	21.73	22.27	29.87
Microseris laciniata	0.63	1.48	0.20	0.50	0.10
Myosotis discolor	0.00	0.00	0.00	0.00	0.00
Orthocarpus sp.	--	0.03	--	--	0.00
Plagiobothrys sp.	0.00	0.00	--	0.03	--

Potentilla gracilis	--	0.30	0.47	--	--
Prunella vulgaris	0.70	0.90	2.87	1.60	1.30
Rosa sp.	14.27	11.82	12.33	10.60	11.27
Rubus armeniacus	--	--	0.33	--	0.27
Rubus laciniatus	--	0.02	0.33	--	--
Sherardia arvensis	0.03	0.07	0.04	0.10	0.23
Sisyrinchium angustifolium	0.27	0.10	0.67	0.33	0.10
Viola odorata	--	0.10	0.20	0.03	--
Vulpia bromoides	--	0.18	--	--	--
Zigadenus venonosus	0.33	0.25	0.27	0.73	--

*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 figures reported.