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

2015

## 2015 Progress Report to the US Army Corps of Engineers, Willamette Valley Projects

Report prepared by Matt A. Bahm and Erin C. Gray

*Institute for Applied Ecology*

## PREFACE

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


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## ACKNOWLEDGEMENTS

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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 (*Anthozanthum odoratum* cover, native species cover, and invasive 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 2015, cover of *Anthoxanthum odoratum* ranged from <1% to 32%. All glyphosate treatments had lower cover than the control and fusilade treatment. Mean native cover varied significantly. Native cover ranged from 5% to 36%, and was significantly higher in control plots than in any of the treatments. In 2015, mean invasive cover ranged from 3% to 47%, and was significantly higher in control plots than in any of the treatments.

In 2015, native graminoid cover ranged from 2% to 30%, with the control plots having significantly higher cover than any of the treatments. Burn + single application of fusilade had significantly higher cover compared to the remaining treatments. Invasive graminoid cover ranged from <1% to 41%, with the control plots having significantly higher cover than any of the treatments. Native forb cover ranged from 2% to 11%, with the glyphosate 2015 treatment significantly lower than the other treatments.

## Fisher Butte

In 2015, *Anthoxanthum* cover ranged from <1% to 10% and varied among treatments. Control plots had the highest cover (10%), followed by burn + single application of fusilade (7%) and burn + single glyphosate application (4%). The glyphosate 2015 and burn + 2 applications of fusilade had <1% cover. Mean native cover ranged from 3% to 19% and varied significantly among treatments. Control, burn + single application of fusilade, and burn + 2 applications of fusilade had the highest native cover, while the glyphosate 2015 treatment had significantly lower native cover. Invasive cover varied among treatments. Mean cover was significantly lower in the glyphosate 2015 (5%), than in any other treatment.

In 2015, native graminoid cover ranged from <1% to 11%, with significantly higher mean cover in the control plots. Although there were significant differences between the remaining treatments, all had <4% mean graminoid cover. Invasive graminoid cover ranged from <1% to 11% and varied significantly among treatments. Patterns were similar to native graminoid cover, but had more overlap among the higher treatment means. Native forb cover ranged from 2% to 16% and varied significantly among treatments. The control and glyphosate 2015 treatment had significantly lower cover of native forbs. Invasive forb cover ranged from 4% to 33% and varied significantly among treatments. The burn + 2 applications of fusilade had the highest invasive forb cover (34%), followed by the burn + single application of fusilade (22%).

# 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 invasive 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 invasive 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 pre-treatment data at Fisher Butte (from 2015).

# METHODS

## 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 invasive 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 invasive 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 invasive 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 Fusliade 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 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 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. 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/earlyJune 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 analysis, while the single treatment 6 plot (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. Fisher Butte map, plot locations, and treatment assignment). Block corners were marked with rebar extending approximately 20 cm above the soil surface. Plot corners within blocks were temporarily marked using 25.4 cm spikes. Plots were permanently marked after the controlled burn with 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 assess 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%.

Fern Ridge was burned October 9, 2014. 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) in February 2012 was inadvertently applied to treatment 6 (surfactant only) plots, and represents a unique unplanned treatment (see Appendix B. Fisher Butte map, plot locations, and treatment assignment). Thus, treatments 2 and 3 (Appendix B. Fisher Butte map, plot locations, and treatment assignment) 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

ANOVA procedures, using JMP Statistical software (JMP 2013), were conducted to determine the effect of each treatment on *Anthoxanthum odoratum* cover, total cover of native and non-native species, native and non-native graminoid cover, native and non-native 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 plants post-treatments in 2012 (Bois 2012), and 40 species in 2015. In addition to the total richness remaining stable, there were no significant differences in the average species richness among the various treatment plots.

### *Anthoxanthum odoratum*

In 2012, cover of *Anthoxanthum odoratum*, our key target invader, ranged from a mean of 5% to 12%, with variation among treatments (Bois 2012), while in 2015 it ranged from <1% to 32% (Figure 5). The burn plus two applications of glyphosate had significantly less *Anthoxanthum* cover ($p = 0.033$) in 2012. In 2015, all glyphosate treatments had lower cover than the control and fusilade treatment ($p=<0.0001$).

### Nativity

In 2012, mean native cover did not differ among plots (Bois 2012), but did vary significantly in 2015 ($p=<0.0001$; Figure 6). Native cover ranged from 5% to 36%, and was significantly higher in control plots than in any of the treatments (Figure 6). The burn + single application of fusilade had the highest cover of any of the treated plots, although there was overlap among the treatment means.

In 2015, mean invasive cover ranged from 3% to 47%, and was significantly higher in control plots than in any of the treatments ($p=<0.0001$; Figure 6). The burn + single application of fusilade had the highest cover of any of the treated plots, although there was overlap among the treatment means Figure 6).

### Graminoid Cover

In 2015, native graminoid cover ranged from 2% to 30%, with the control plots having significantly higher cover than any of the treatments ($p=<0.0001$). Among the treatments, the burn + single application of fusilade had significantly higher cover compared to the remaining treatments (Figure 7).

In 2015, invasive graminoid cover ranged from <1% to 41%, with the control plots having significantly higher cover than any of the treatments ($p=<0.0001$). The glyphosate 2015 treatment had the lowest cover of the treatments, although there was overlap in the treatment means (Figure 7).

### Forb Cover

In 2015, native forb cover ranged from 2% to 11%, with the glyphosate 2015 treatment significantly lower than the other treatments ($p=0.0254$). The burn + 2 applications of glyphosate (Glyphosate 2x) and burn + single application of fusilade had the highest cover of native forbs, although not significantly higher than the control and burn + single application of glyphosate (Figure 8).

In 2015, invasive forb cover ranged from 4% to 16%, but did not vary significantly among treatments ($p=0.1001$; Figure 8).

### Substrate

In 2015, cover of bare ground and litter was variable across plots (Figure 9). Both bare ground ($p=0.0133$) and litter ($p=0.0006$) varied significantly among treatments. Bare ground was highest in the single and double application of glyphosate, and single application of fusiladefusilade, with the control and glyphosate 2015 treatment having similar levels (Figure 9). Litter was highest in the control and glyphosate 2015 treatment and lower in the treatments with higher bare ground cover (Figure 9).

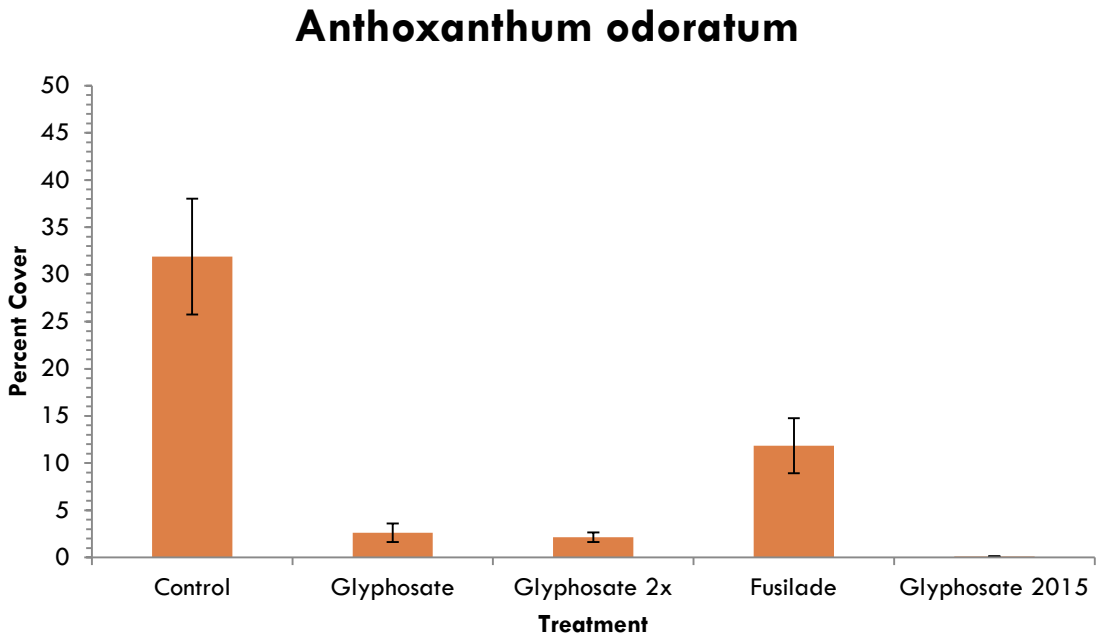


**FIGURE 5. *ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE 2015 (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION, FOLLOWED BY GLYPHOSATE IN 2015). *NOTE SCALE WITH MAXIMUM OF 50%.**

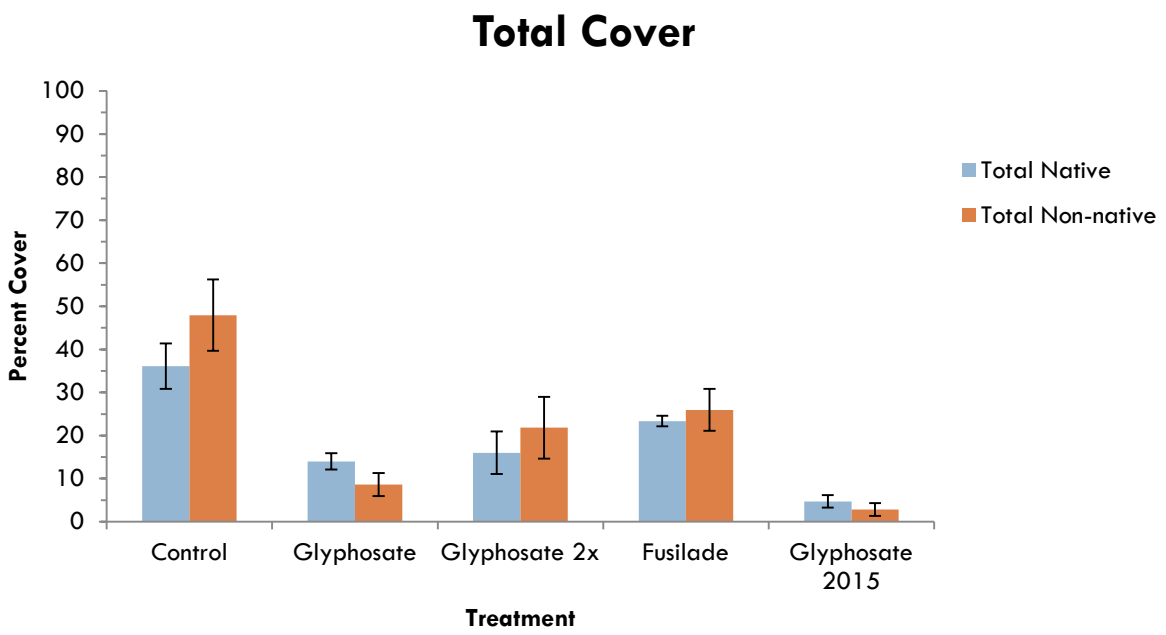


**FIGURE 6. TOTAL NON-NATIVE AND NATIVE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE 2015 (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION, FOLLOWED BY GLYPHOSATE IN 2015).**

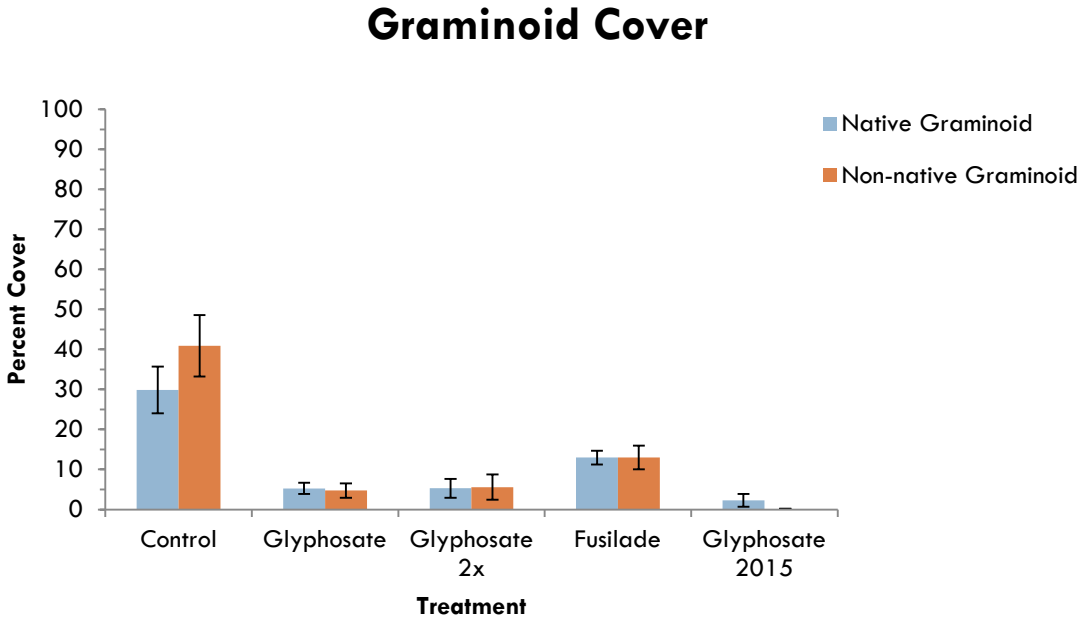


**FIGURE 7. NATIVE AND NON-NATIVE GRAMINOID COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE 2015 (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION, FOLLOWED BY GLYPHOSATE IN 2015).**

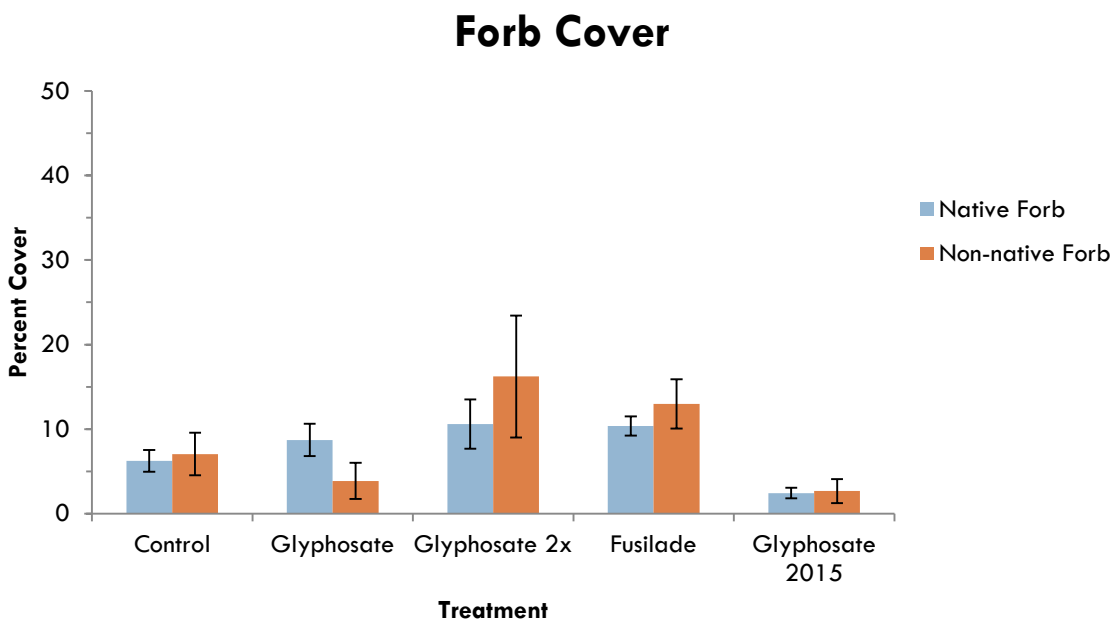


**FIGURE 8. NATIVE AND NON-NATIVE FORB COVER AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE 2015 (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION, FOLLOWED BY GLYPHOSATE IN 2015). *NOTE SCALE WITH MAXIMUM OF 50%.**

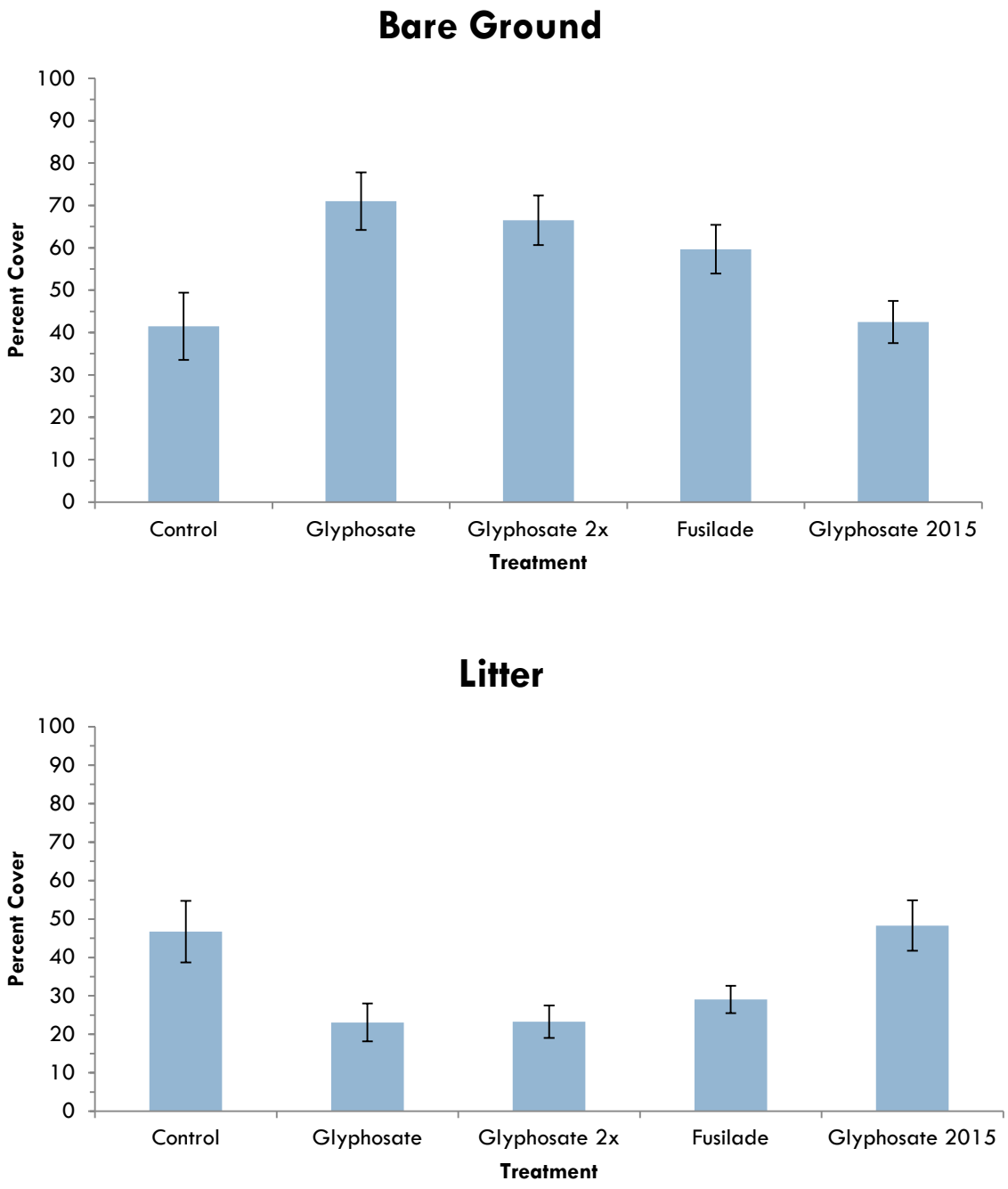


**FIGURE 9. SUBSTRATE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE 2015 (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION, FOLLOWED BY GLYPHOSATE IN 2015).**

## 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 post-treatment in 2015. Cover of *A. odoratum* averaged 35.8% ± 1.15%. As at Rose Prairie, cover of *A. odoratum* varied slightly between blocks (Appendix G.). Cover of exotic species varied among blocks as well and was higher at Fisher Butte than Rose Prairie. At Fisher Butte average exotic cover ranged from 40% to 65%. Average native species cover in each block ranged from 35% to 64%. Average exotic species richness ranged from 7 to 9.5 species; native species richness ranged from 8.5 to 9.6 species. Cover of litter was generally high across blocks. Bare ground cover was variable and moderate; there was minimal moss cover (Bois 2012).

### *Anthoxanthum odoratum*

Pretreatment cover of *Anthoxanthum* ranged from 15% to 35% (Appendix G). In 2015, cover ranged from <1% to 10% and varied among treatments (p=0.0001; Figure 10). Control plots had the highest cover (10%), followed by burn + single application of fusilade (7%) and burn + single glyphosate application (4%). The glyphosate 2015 and burn + 2 applications of fusilade had <1% cover (Figure 10).

### Nativity

In 2015, total native cover ranged from 3% to 19% and varied significantly among treatments (p=<0.0001; Figure 11). Control, burn + single application of fusilade, and burn + 2 applications of fusilade had the highest native cover, while the glyphosate 2015 treatment had significantly lower native cover (Figure 11).

In 2015 mean invasive cover was more variable than mean native cover (Figure 11), but also varied among treatments (p=<0.0001). Mean cover was significantly lower in the glyphosate 2015 (5%), than in any other treatment. The burn + 2 applications of fusilade had the highest invasive cover, although statistically, it overlapped with the other treatments (Figure 11).

### Graminoid Cover

In 2015, native graminoid cover ranged from <1% to 11%, with significantly higher mean cover in the control plots (p=<0.0001; Figure 12). Although there were significant differences between the remaining treatments, all had <4% mean graminoid cover (Figure 12).

In 2015, invasive graminoid cover ranged from <1% to 11% and varied significantly among treatments (p<0.0001; Figure 12). Patterns were similar to native graminoid cover, but had more overlap among the higher treatment means. The control and burn + single application of fusilade had the highest invasive cover, and the glyphosate 2015 and burn + 2 applications of fusilade had <1% mean invasive cover (Figure 12).

### Forb Cover

In 2015, native forb cover ranged from 2% to 16% (Figure 13) and varied significantly among treatments ($p<0.0001$). Burn + single application of fusilade had the highest cover (16%), but with statistical overlap in the burn + 2 applications of fusilade (14%) and burn + single glyphosate application (12%). The control and glyphosate 2015 treatment had significantly lower cover of native forbs (Figure 13).

In 2015, invasive forb cover ranged from 4% to 33% (Figure 13) and varied significantly among treatments ($p<0.0001$). The burn + 2 applications of fusilade had the highest invasive forb cover (34%), followed by the burn + single application of fusilade (22%), and statistically similar lower cover in the remaining treatments (Figure 13).

### Substrate

In 2015, bare ground was generally high and varied significantly among treatments ($p=0.0032$). The burn + single glyphosate application had the highest cover of bare ground (83%), but all treatments had >59% bare ground cover and showed statistical overlap among means (Figure 14). Litter cover ranged from 5% to 25% and varied significantly among treatments ($p=<0.0001$; Figure 14). The glyphosate 2015 treatment had the highest litter cover and control plots had the lowest litter cover (Figure 14). The burn + 2 applications of fusilade, burn + single application of fusilade, and burn + single glyphosate application had statistically similar mean litter cover (Figure 14).

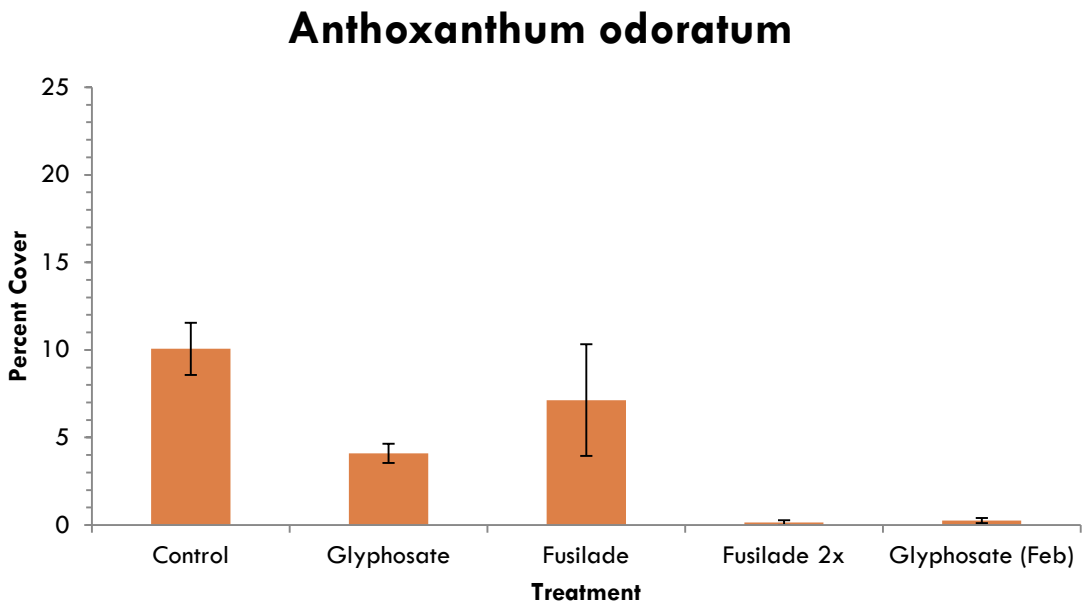


**FIGURE 10. *ANTHOXANTHUM ODORATUM* COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT FISHER BUTTE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), GLYPHOSATE 2X (BURN AND 2 GLYPHOSATE APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND SURFACTANT ONLY (BURN FOLLOWED BY A SURFACTANT ONLY APPLICATION). *NOTE SCALE WITH MAXIMUM OF 25%.**

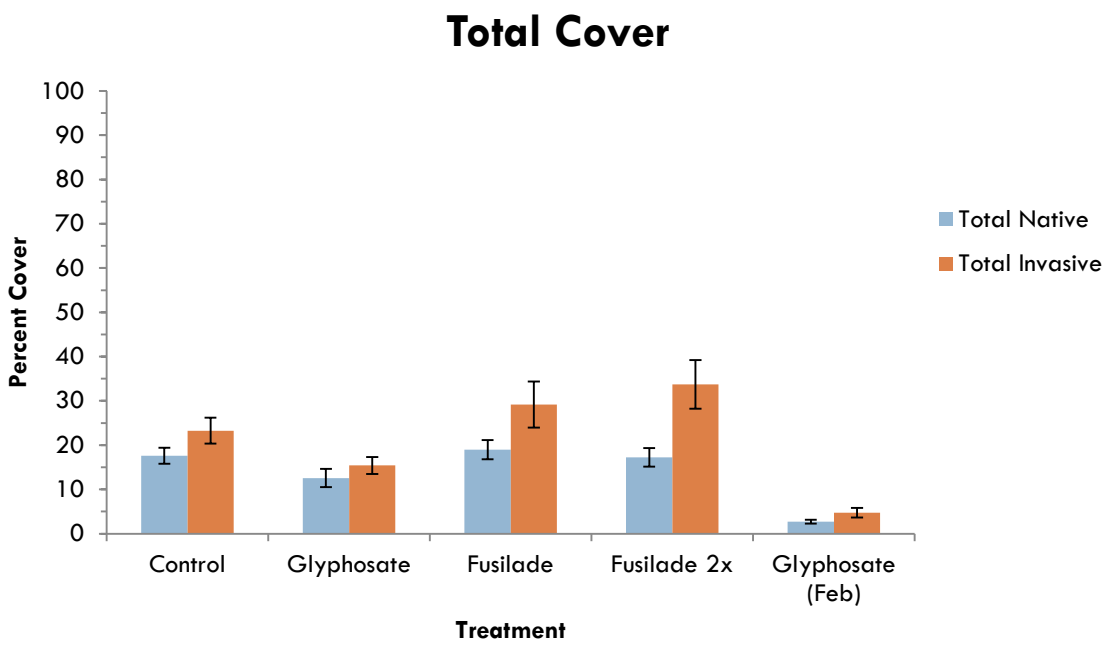


**FIGURE 11. TOTAL NATIVE AND NON-NATIVE PLANT COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), SETHOXYDIM (BURN AND SETHOXYDIM APPLICATION), SETHOXYDIM 2X (BURN AND 2 SETHOXYDIM APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE (FEB) (BURN FOLLOWED BY A GLYPHOSATE APPLICATION IN THE FEBRUARY FOLLOWING THE BURN).**

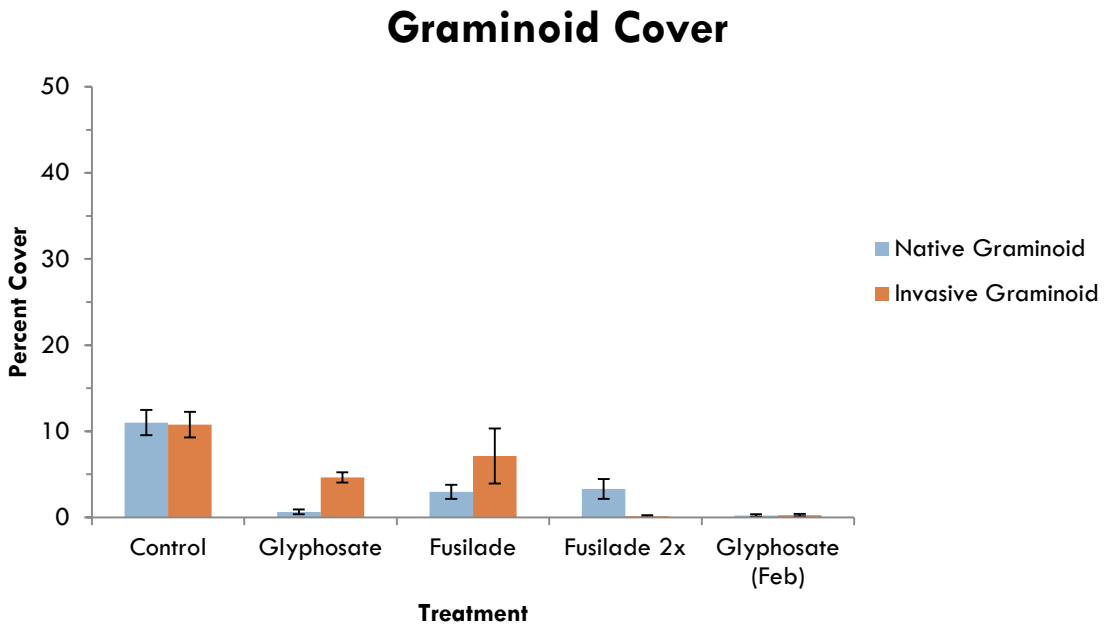


**FIGURE 12. NATIVE AND NON-NATIVE GRAMINOID COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), SETHOXYDIM (BURN AND SETHOXYDIM APPLICATION), SETHOXYDIM 2X (BURN AND 2 SETHOXYDIM APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE (FEB) (BURN FOLLOWED BY A GLYPHOSATE APPLICATION IN THE FEBRUARY FOLLOWING THE BURN). *NOTE SCALE WITH MAXIMUM OF 50%.**

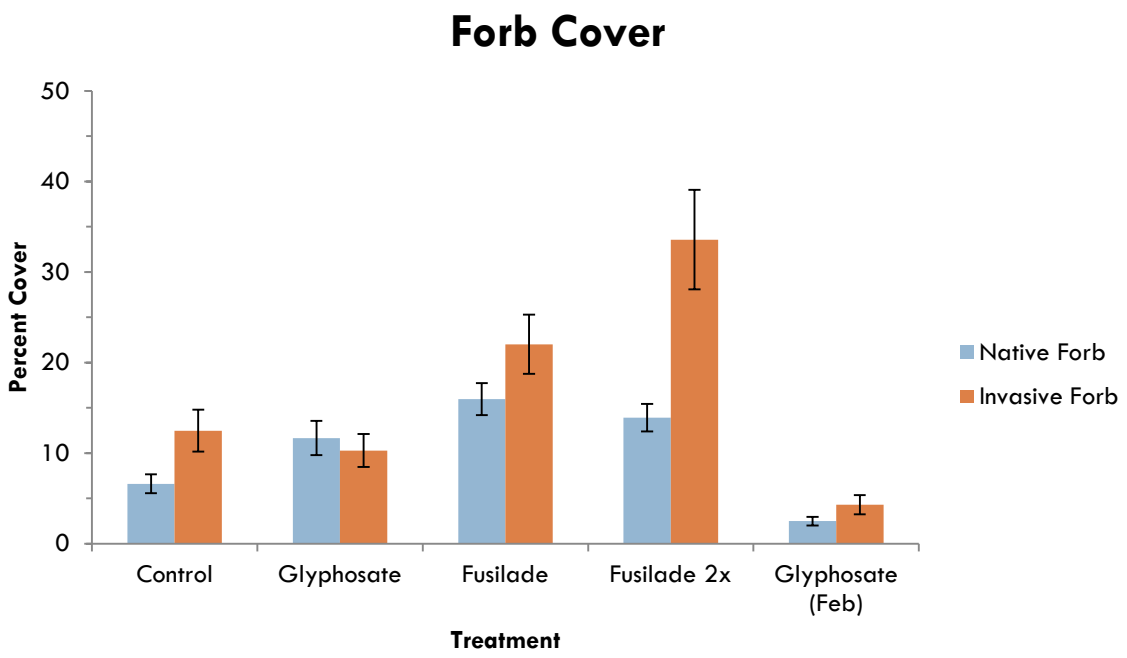


**FIGURE 13. NATIVE AND NON-NATIVE FORB COVER AT FISHER BUTTE EXPERIMENTAL PLOTS IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), SETHOXYDIM (BURN AND SETHOXYDIM APPLICATION), SETHOXYDIM 2X (BURN AND 2 SETHOXYDIM APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE (FEB) (BURN FOLLOWED BY A GLYPHOSATE APPLICATION IN THE FEBRUARY FOLLOWING THE BURN). *NOTE SCALE WITH MAXIMUM OF 50%.**

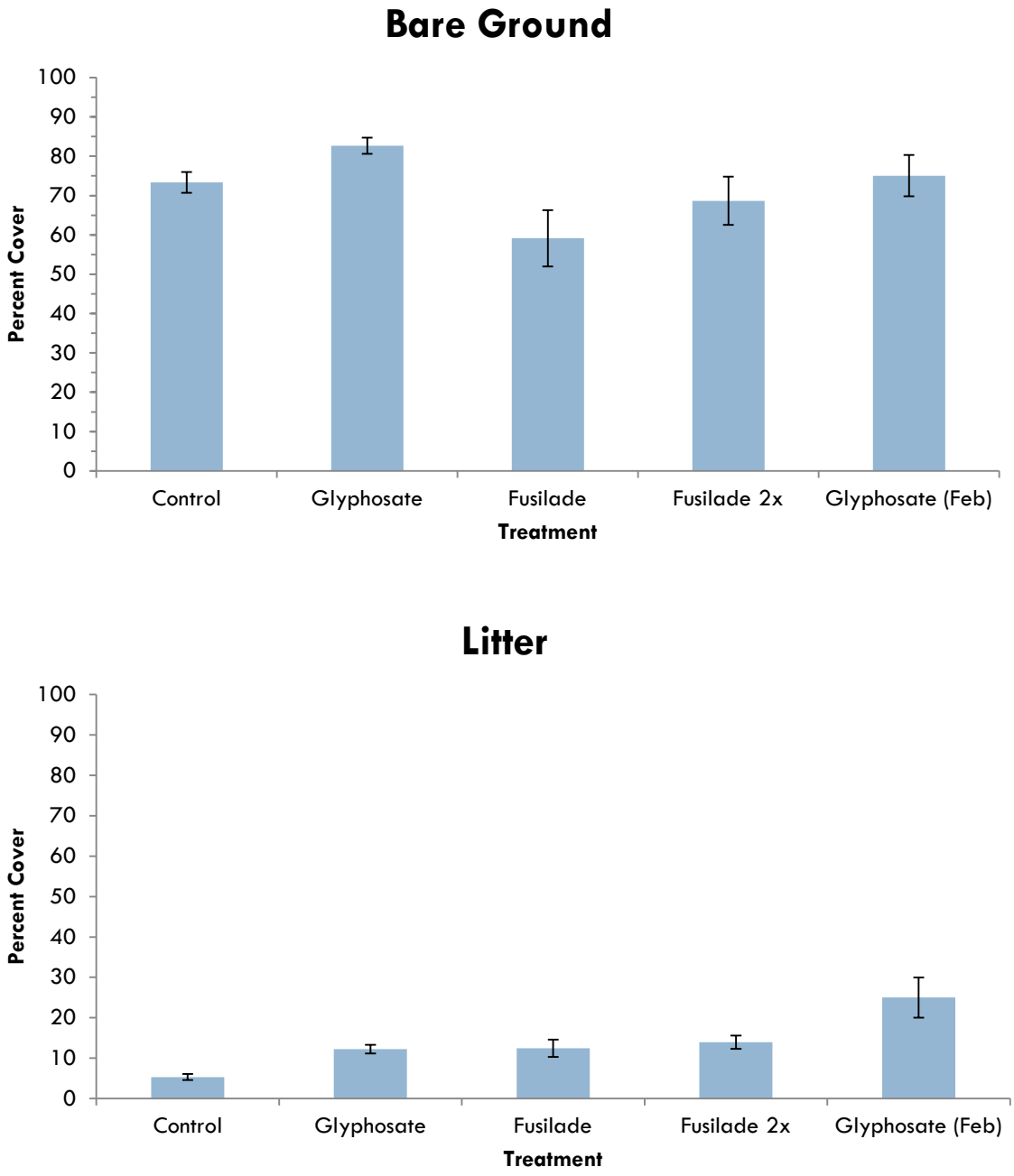


**FIGURE 14. SUBSTRATE COVER POST-TREATMENT AT EXPERIMENTAL PLOTS AT ROSE PRAIRIE IN 2015. DATA ARE MEANS ± SE. TREATMENT PLOTS ARE CONTROL (BURN ONLY), GLYPHOSATE (BURN AND 1 GLYPHOSATE APPLICATION), SETHOXYDIM (BURN AND SETHOXYDIM APPLICATION), SETHOXYDIM 2X (BURN AND 2 SETHOXYDIM APPLICATIONS), FUSILADE (BURNING FOLLOWED BY A FUSILADE TREATMENT) AND GLYPHOSATE (FEB) (BURN FOLLOWED BY A GLYPHOSATE APPLICATION IN THE FEBRUARY FOLLOWING THE BURN).**

# DISCUSSION

Rose Prairie and Fisher Butte are relatively high quality wetland prairies, with a moderately diverse native plant community and few non-native species. However, aggressive, fire-tolerant, non-native grasses pose a large risk to remnant wetland prairies. We found *Anthoxanthum odoratum* is present at both Rose Prairie and Fisher Butte, and total non-native cover is relatively high. Finding efficient management strategies to reduce invasive 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 invasive 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

The treatments that included glyphosate herbicide reduced cover of *Anthoxanthum* compared to the control and fusilade treatment. Fusilade, a grass-specific herbicide, was selected to minimize non-target species damage common with a broad-spectrum herbicide like glyphosate. The single application was not as effective as treatment(s) containing glyphosate, but likely would have been more effective with the second application as seen at Fisher Butte.

All herbicide treatments reduced the total cover of graminoids, regardless of nativity. The control plots had the highest cover of both native and invasive graminoid species. All herbicides used had negative impacts to both the native and invasive graminoid component of the vegetation community and future monitoring will be important to determine the recovery of native graminoids in relation to invasive graminoids.

The native forb component did vary among treatments, with the glyphosate 2015 treatment having the most detrimental impact. This is likely due to the timing of this treatment, which coincided with early growth of many native species (personal observation). While glyphosate treatment did show potential for reducing target species, timing of application is critical to minimize damage to non-target species (Tesfamariam et al. 2009). We did not record a difference in invasive forbs in any treatment, and this group does not warrant further control efforts at this time.

Future monitoring will provide information on plant community responses to the treatments, and suggestions on future efforts can be made. For 2016, we do not recommend any additional treatment.

## Fisher Butte

All plots had lower cover of *Anthoxanthum* (<1% to 10%), compared to pretreatment cover values (15% to 35%). These data indicate that the burn conducted prior to treatment application caused a reduction in *Anthoxanthum* cover and future monitoring will help to determine how long the impacts will last. The glyphosate 2015 and burn + 2 applications of fusilade reduced *Anthoxanthum* to <1% cover, but also had negative impacts to native graminoid and native forb cover.

Graminoid cover showed a similar pattern, regardless of nativity. Treatments that effectively reduced invasive graminoid cover also reduced native species cover. None of the treatments provide a recommended alternative at this time and future monitoring will determine the best method(s) for future efforts.

All treatments reduced native forb cover compared to the control. This was expected for glyphosate, a broad-spectrum herbicide, but was not for the grass-specific herbicide, fusilade. Derr (1987) found that the active ingredient in fusilade (fluazifop) was phytotoxic to azalea when combined with an adjuvant. It is possible that the combination of fusilade and Nu-film used in our study is phytotoxic to certain forb species. Invasive forb cover was relatively high in all plots (10% - 30%), except the glyphosate 2015 (<5%). The increase in forb cover is dominated by *Hypochaeris radiata*. This species may require future control efforts, but we want to continue monitoring of plots in 2016 before suggesting control efforts that may be detrimental to native forb cover.

Future monitoring will provide information on plant community responses to the treatments, and suggestions on future efforts can be made. For 2016, we do not recommend any additional treatment.

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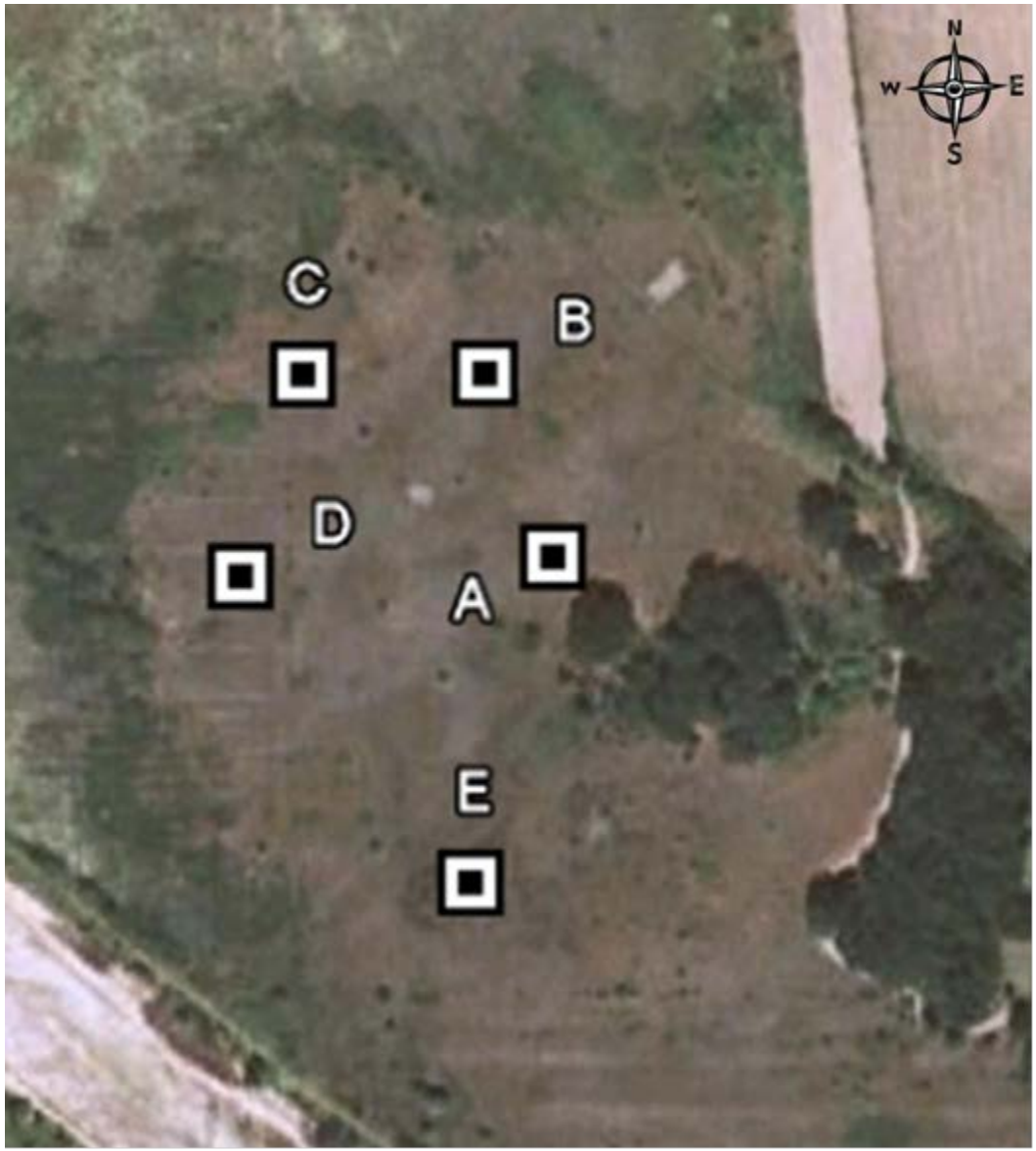
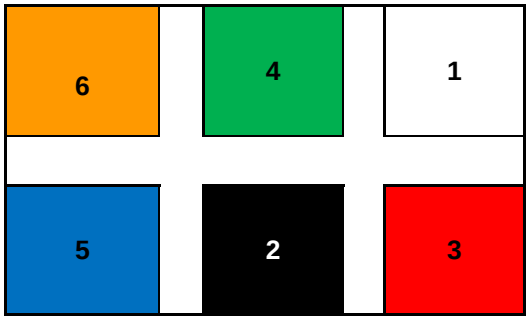
# APPENDIX A. ROSE PRAIRIE MAP, PLOT LOCATIONS, AND TREATMENT ASSIGNMENTS



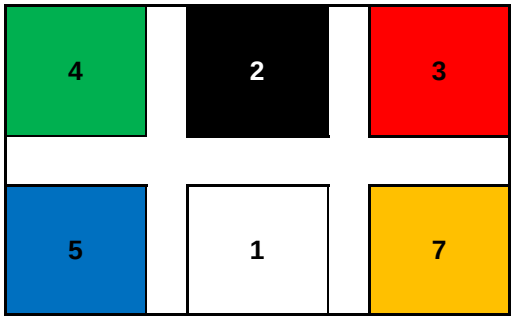

Locations of Rose Prairie macroplots. Origins (tall conduit or rebar) are in the NE corner, except for plot D, where the origin is in the NW corner.

| 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 |

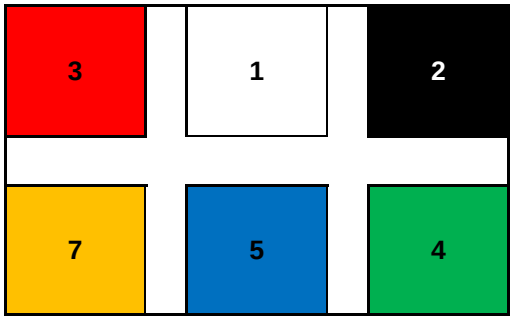
**Rose Prairie A**



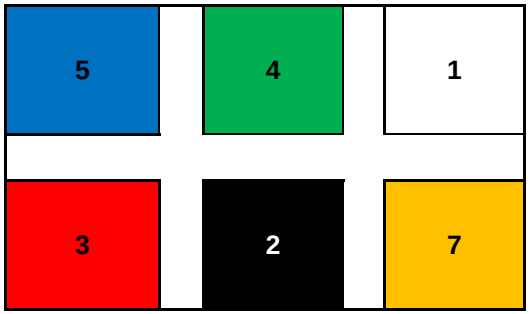

**Rose Prairie C**



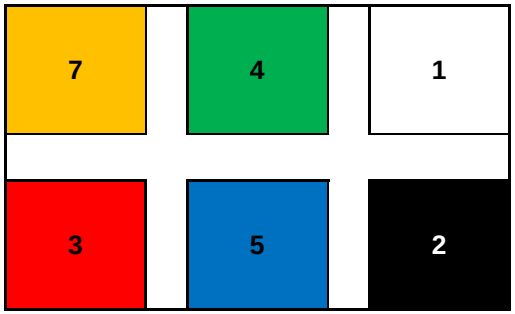

**Rose Prairie E**




**Rose Prairie B**




**Rose Prairie D**

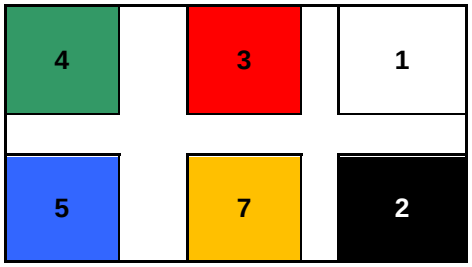



**Treatments**

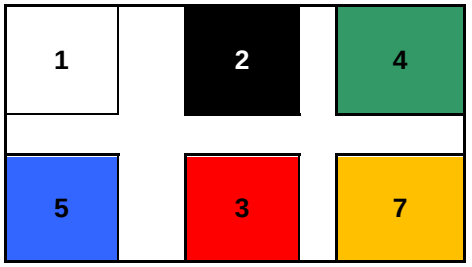
1 Control
2 Glyphosate 1-2 weeks post-fire
3 Glyphosate 1-2 weeks post-fire & February glyphosate
4 Fusilade 1-2 weeks post-fire
5 Fusilade 1-2 weeks post-fire and Fusliade February 2015 (Plot A was not sprayed in 2015 due to standing water)
6 Surfactant only (Removed from analysis due to only a single sample)
7 Glyphosate February 2015 (Inadvertantly applied to Surfactant Only Plots)

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

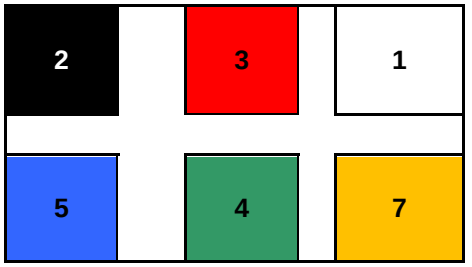
**Fisher Butte 1**



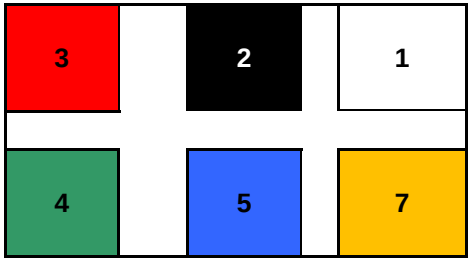

**Fisher Butte 3**



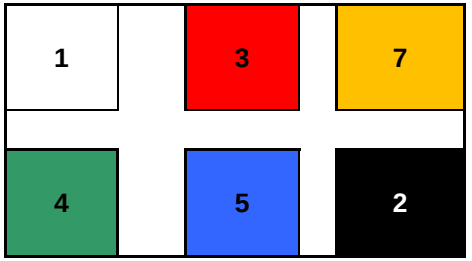

**Fisher Butte 5**




**Fisher Butte 2**




**Fisher Butte 4**




**Treatments**

| | |
|---|---|
| 1 | Control |
| 2 | Glyphosate 1-2 weeks post-fire |
| 3 | February glyphosate treatment was inadvertently applied to Surfactant plots so 2 and 3 were combined for analysis |
| 4 | Fusilade 1-2 weeks post-fire |
| 5 | Fusilade 1-2 weeks post-fire & February Fusilade |
| 7 | Glyphosate February 2015 |

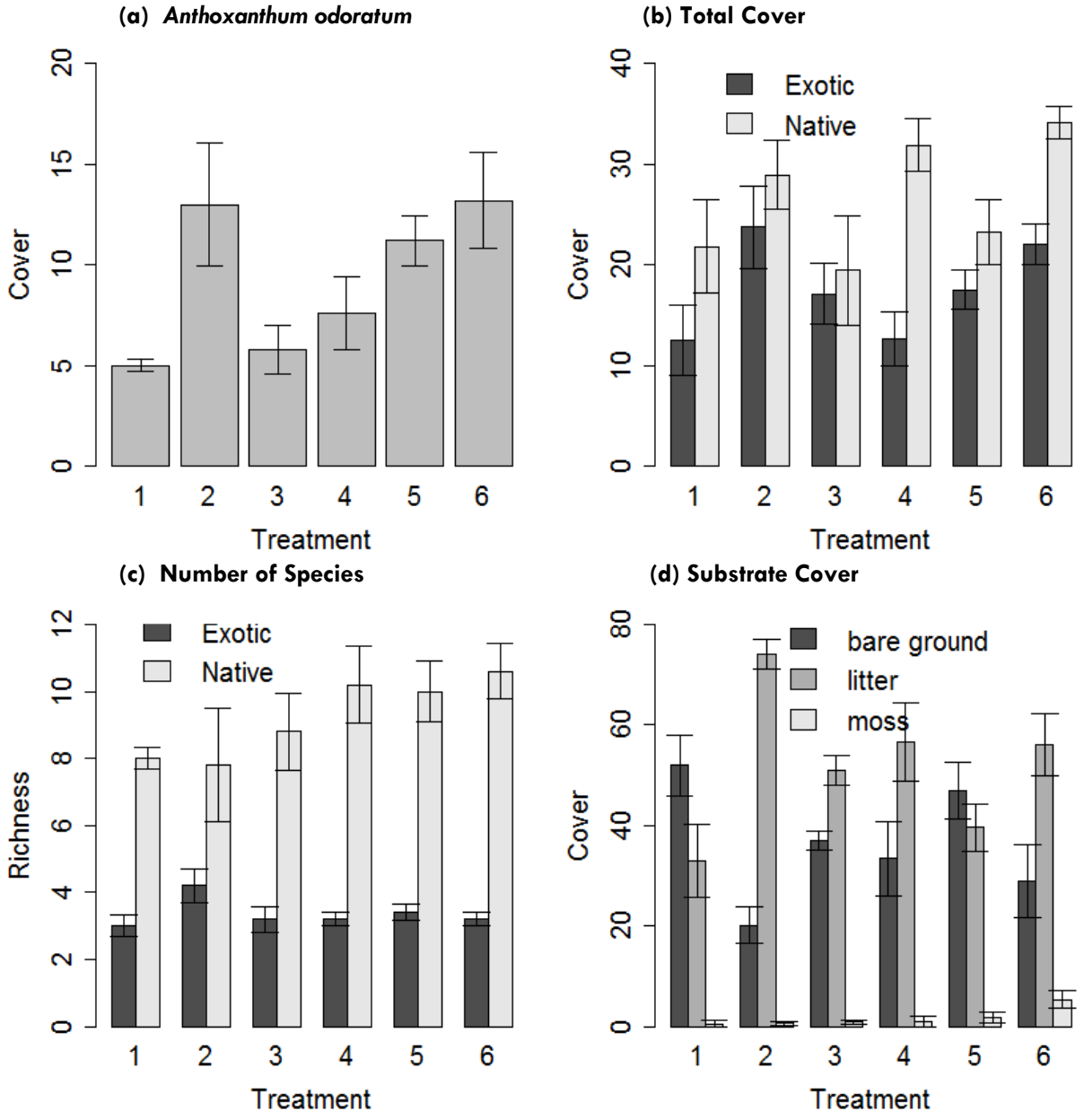
# APPENDIX C. AVERAGE COVER OF ALL SPECIES OBSERVED IN MONITORING PLOTS AT ROSE PRAIRIE IN 2010

| | 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 venonosus* | -- | -- | 0.02 | 0.02 | -- |

# APPENDIX D. 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 E. 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 NON-NATIVE PLANT, (C) NUMBER OF NATIVE AND EXOTIC SPECIES PER PLOT, AND (D) COVER OF BARE GROUND. DATA ARE MEANS ± 1SE.



# APPENDIX F. 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 |

# APPENDIX G. 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 NON-NATIVE PLANT, (C) NUMBER OF NATIVE AND EXOTIC SPECIES PER PLOT, AND (D) COVER OF BARE GROUND. DATA ARE MEANS ± 1SE.