Plant Community Monitoring at the Lac Qui Parle WMA/Chippewa Prairie Patch-Burn-Graze Project

Progress Report
to MNDNR and The Nature Conservancy
for the 2013 Field Season

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Figure 1: Location of management units and plot pairs (light blue dots) in the LQP/Chippewa project area (the first number in each plot label refers to the number of the management unit in which it occurs).

Acknowledgements

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Carmen Converse organized funding for this project and provided input into many aspects of it. John Giudice provided statistical advice and assistance, and wrote the R code for the mixed-model analysis. John Giudice, Robert Dana, Daniel Wovcha, and Chris Helzer reviewed drafts of this report. Joe Blastick, Dave Trauba, and their crews constructed exclosures. Dave Trauba and staff provided the use of a Polaris Ranger, without which our task would have been much more difficult. Scott Zager (Wildlands Ecological Services), Dustin Graham (University of Northern Iowa), Ben Hoksch (University of Northern Iowa), and Paul Bockenstedt (Stantec Inc.) sampled the vegetation in 2011 and/or 2013. Laura Triplett and Janeen Ruby assisted with the entry and quality control of field data. Norm Aaseng created a field data entry program in MS Access.

Summary

This interim report presents results from two years of vegetation monitoring of 25 pairs of vegetation plots at the Lac Qui Parle/Chippewa Prairie Patch-Burn-Graze (pbg) project. The plots were distributed over 5 management units within Lac Qui Parle WMA and Chippewa Prairie Preserve (Figure 1). One plot within each pair was randomly selected and enclosed within a 20-m diameter exclosure constructed of cattle panels. In 2011, the vegetation was sampled before cattle were released into the project area. Grazing was started in 2012. The second year of vegetation sampling was in 2013. Unit 1 was burned in 2010, unit 5 was burned in 2012, and unit 4 was burned in 2013. In 2013, unit 5 was required to be fenced off from the rest of the pbg project. Also in 2013, a 90 acre portion of unit 5 was fenced off from the rest of the unit and grazed in order to examine the effects of two consecutive years of grazing on sweet clover. Two years are not enough time to assess management impacts on systems composed primarily of long-lived, perennial plants and all vegetation sampling results must be seen as preliminary. Some observations and results were:

- In units 1 (burned in 2010) and 5 (burned in 2012), controlled burns within the project area stimulated the germination of sweet clover, which formed dense patches the second growing season after the burn. Conversely, there is little sweet clover germinating in unit 4 (burned in 2013).

- In general, the intensity of the grazing treatment in burn patches has been variable. Grazing in 2012 (0.52 -0.58 AUMs/acre) followed an expected pattern with heavy use of the unit 5 burn patch, moderate use of the adjacent unit 4, and much less use of other units. Patch-burn grazing in 2013 (0.35-0.42 AUMs/acre), with a lower stocking rate than 2012, had a somewhat different pattern of less intensive use of the burn patch (unit 4) and a greater spread of grazing intensity across adjacent units. This different pattern is likely due to factors other than stocking rate. In September, the cows spent most of their time on the lower terrace (unit 7), where there was more palatable forage late in the season (Trauba, pers. comm.).

- Mean Visual Obstruction Reading (VOR), an index of vegetation structure, was reduced from 2011 to 2013 to a significantly greater extent in grazed plots than exclosures in all management units. In unit 1, this was primarily the result of the loss of sweet clover stimulated by a 2010 burn. In units 2-3 the reduction in mean VOR was slight and may represent the lower level of grazing in plots that were not burn patches. There was a greater reduction in mean VOR from 2011 to 2013 in the grazed plots of unit 4, reflecting a greater amount of grazing in the 2013 burn patch than in units 1-3.

- In 2013, the grazing of 90 acres of unit 5 was nearly three times more intensive than in other years or units (1.37 AUMs/acre). Grazing in the year of the burn combined with intensive grazing over the following season reduced the height (VOR) of sweet clover and other vegetation to levels that were lower than the 2011 pre-grazing condition. The unit 5 plots that were only grazed in the year of the burn (2012) also had reduced mean VOR compared to exclosures, though mean VOR was still greater than the pre-grazing condition. In all instances, sweet clover flowered and set seed. Although fencing and

"double grazing" of unit 5 provided some interesting short-term results, it also complicated the evaluation of pbg effects for the larger management area (e.g., the treatments are no longer similar).

- Approximately 175 plant species were recorded in the project area, which was reduced to a total of 150 taxa for data analysis by combining some species.

- In units 1-4, mean total, native and exotic species richness showed little change from 2011 to 2013 in grazed and exclosure plots.

- In the most heavily grazed portion of the project (unit 5), mean total plant species richness increased in both grazed and exclosure plots from 2011 to 2013 due to increases in both native and exotic species. In this unit, the change in mean native species richness from 2011 to 2013 in grazed plots was not significantly different from exclosures (both increased). The change in mean exotic species richness from 2011 to 2013 was significantly different, statistically, between grazed and exclosure plots, as mean exotic richness increased in grazed plots but not in exclosures. This effect involved only a few species and it remains to be seen if this is a trend, a pulse response, or simply an artifact of conditions at the time of sampling.

- The apparent increase in Canada goldenrod in unit 5 after intensive grazing may be due to the temporary removal of other vegetation that hides this species and not an increase due to grazing. Canada goldenrod is superabundant in this unit due to its recent, past history of severe overgrazing before this unit was acquired as part of the WMA.

- The mean frequency (in both 0.1 and 1-m^2 quadrats) and mean cover of smooth brome increased slightly in nearly every management unit in 2013 compared to 2011. The magnitude of this change was not large enough to be statistically significant. Future sampling will show if this is part of a trend of smooth brome expansion in the project area.

- Some wet soils in swales within the project area have been churned up by cattle, resulting in exposed bare soils. At least some of these wet spots were high quality wet prairie dominated by native species, such as bluejoint (*Calamagrostis canadensis*), before grazing (Dana 2013). We do not know how many such places are present in the project area, or if the exposed soils are going to be colonized by invasive species, thus shifting dominance from native to invasive species. In 2014, we will assess how prevalent this issue is in the site and establish vegetation transects in these areas to monitor them. Wet areas in portions of the project area that have not yet had intensive grazing may give us a better chance to assess the pre-grazing condition of these features.

Introduction

Conservation grazing is a relatively new tool for managing prairies in Minnesota, yet few data have been collected on its effect on species composition of the northern and more mesic prairies present in Minnesota at the eastern edge of the northern tallgrass prairie region. Previous studies have focused on much larger prairie landscapes composed predominantly of drier prairie types in the central or southern Great Plains. This project seeks to assess the effects of the grazing component of patch-burn-grazing on plant species composition in the more mesic and northern prairie communities that occur in Minnesota. Patch-burn-grazing involves fencing only the outer perimeter of a large area divided into several burn units, in which each unit is burned in a different year. Cows are free to go wherever they want within the fenced area. If stocking rates are correct and water sources are well distributed, cattle will generally focus most on grazing the most recently burned unit and least on the unit that has had the longest time since the last burn. Over time, the rotation of burns, grazing pressure, and rest periods results in a shifting mosaic of patches of different structure across the fenced area (Fuhlendorf and Engle 2004). We chose to sample mesic prairie on level or nearly level uplands, which makes up over 80% of the prairie within the project area.

Methods

Management to Date

The first unit was burned in May 2010, vegetation sampling was initiated in the summer of 2011, and conservation grazing was started in June 2012 (Table 1). The original plan was for one unit to be burned every other year and for cattle to have access to all five units during June-September (for more detailed information on the study design, and a literature review, see Harris 2013). Since 2012, a new unit has been burned every year. After the 2012 season, unit 5 was fenced off from the rest of the project area and was further subdivided by a temporary interior fence to allow more intensive grazing of dense patches of sweet clover (Table 1). Thus, unit 5 is no longer representative of the open patch-burn-grazing system being evaluated, but may still provide useful information on an individual-unit basis because unit 5 was in relatively poor condition due to historical grazing activities. In addition to fencing unit 5, cattle stocking rates were reduced in 2013 (Table 2; also see stocking rate calculations, below).

2013 Vegetation Sampling

This project involves sampling all plant species every 2 years within pairs of permanent 10-m x 10-m plots that were established in five management units (Fig. 1; also see Harris 2013) using a stratified random design with a 300-m minimum distance between plot pairs. One member of each plot pair was randomly selected to be excluded from grazing with a 20-m-diameter circular exclosure constructed of cattle panels. Exclosures enable us to separate the effect of grazing from other variables that may affect plant community composition (e.g., prescribed fire, environmental conditions). Within each 10-m x 10-m plot, we recorded all plant species present in nested 0.1-m^2 and 1-m^2 quadrats, and visually estimated cover to the nearest 1% of all species present in the 1-m^2 quadrats.

In 2013 for the first time, we digitally recorded monitoring data in tablet computers. A program for data entry was created in MS Access by Norm Aaseng of the MNDNR's Minnesota Biological Survey (MBS). The tablets worked very well in the field, greatly increased the accuracy of recorded data, and greatly reduced the time involved in data entry and quality control.

Plants of unknown or uncertain identity were collected and pressed. These were examined later and identified where possible. Corrections were made to the recorded data. In 2013, several plant taxa were pooled into taxonomic groups for the purposes of analysis (Table 3). These included species present mostly as vegetative plants that could not reliably be separated from other species, or where not all individuals could be identified to species. Beginning in 2013, we digitally recorded monitoring data using tablet computers. A program for data entry was created in MS Access by Norm Aaseng of the MNDNR's Minnesota Biological Survey (MBS). The tablets worked very well in the field, greatly increased the accuracy of recorded data, and greatly reduced the time involved in data entry and quality control.

We originally planned to record the numbers of cow pies present in each 1-m^2 quadrat as a measure of cow visitation and grazing intensity within each plot. As this was before cows were released into the project, there were no cow pies to record. Later, we realized that this would be a poor index of grazing intensity because cows may likely deposit pies in different locations from where they graze. In 2013, instead of recording the number of cow pies present within each 1-m^2 quadrat, we measured the height of the tallest grass (leaf or stem) located within 5 cm of the NE corner of each 0.1-m^2 quadrat. This was to obtain a better measurement of within-plot grazing intensity. Unfortunately, we do not have comparable data for the 2011, pre-grazing sampling.

For this report, a subset of vegetation response metrics were summarized using simple arithmetic means and SEs for each year, unit, and plot type (exclosure vs. grazed). More specifically, bar plots were constructed for mean vegetation height (VOR), species richness, and mean frequency or cover for selected species of interest. These qualitative summaries are not intended to be formal tests of treatment effects; rather, they are helpful for visualizing how response metrics varied among units, years, and plot types. More formal testing and estimation of treatment effects will be done using a repeated-measures ANOVA approach (see Harris 2013). John Giudice, DNR statistician, ran statistical tests of the selected response metrics using mixed model analysis-of-deviance tests. See appendix B for his description of the statistical analyses.

Table 1: Timeline of Management and Vegetation Sampling Events to Date, with Some Observations:

Date	Event	Observations
May, 2010	Unit 1 burn	
27 July – 12 Aug, 2011	Paired plot veg sampling	Much of unit 1 had dense patches of tall sweet clover which germinated following the previous year's burn.
Fall, 2011	Exclosures installed	Perimeter fence also completed in spring 2012.
12 May, 2012	Unit 5 burn	
5 June – 29 Sept, 2012	Grazing in Units 1-5	106 cow/calf pairs, 100 heifers, and 6 bulls released into project for the first time, with access to Units 1-5 (2,767 total fenced area, including non-grazable areas [marshes, etc.] and lower terrace, of which 1,969 acres occurs on the upper terrace within the pbg burn units). Following an expected pattern, the cows and calves were generally observed to stay on the burn patch (i.e., unit 5) for a large percentage of the time, with some activity in the adjacent unit 4, and little activity in units 1-3.
Spring, 2013	Unit 5 fenced	Unit 5 was fenced off from the rest of the project area.
7 May, 2013	Unit 4 burn	Total burn area was 540 acres including the newly acquired Teliford tract (now unit 6). 303 acres of the burn unit were within the fenced pasture and available for grazing.
3 June – 17 Sept, 2013	Grazing in Units 1-4	101 cow/calf pairs and 4 bulls were released into units 1-4 (2,469 total fenced acres, including non-grazable areas [marshes] and lower terrace, of which 1,611 acres occurs on the upper terrace within the pbg project area). In contrast to the pattern in 2012, Cows and calves were generally observed to spend less time on the burn patch (unit 4), at least early in the season, and spent more time roaming across the other available management units (1-3). Nevertheless, they did graze unit 4 more than units 1-3.
3 June – 17 Sept, 2013	Part of Unit 5 grazed	90 acres on the east side of unit 5 were fenced off with temporary fencing and grazed with 34 heifers and 2 bulls for a second year of grazing ("double grazing"). Sample plots 5-4 and 5-5 are within this double-grazed portion of the unit. Sample plots 5-1, 5-2, and 5-3 were not grazed in 2013. Stocking rate was much heavier than other grazing in project.
24 July – 1 Aug, 2013	Paired plot veg sampling	Vegetation sampling of all 25 plot pairs over 9 days. Much of unit 5 had dense patches of tall sweet clover that germinated after the 2012 burn.
Sept, 2013	Well installed	New well installed at the border between units 4 and 3, located a few hundred yards west of main parking lot.

Table 2: Animal Unit (AU) Calculations for 2012 and 2013 Compiled by Dave Trauba.

2012 Animal Units (PBG Units 1-5)

Actual weights from Travis 1-16-13 - these weights received after 2012 grazing season				
Animal Type	Number	Actual weights[1]	AU per type	Actual AU
Heifer	100	900	0.92	92
Cow/Calf	106	1900	1.5[2]	159
Bull Mature	5	1600	1.6	8
Bull Yearling	1	1400	1.4	1.4
Totals	212			**260.4**

[2] 1.5 AU/cow-calf pair was based on Utah State University Cooperative Extension.
[1] Actual weights not received until after grazing season.

2013 Animal Units (PBG Units 1-4)

Animal Type	Number	Actual weights	AU per type	Actual AU
Cow/Calf	101	1900	1.8[1]	181.8
Bull Mature	4	1600	1.6	6.4
Totals	105			**188.2**

[1] 1.8 AU/cow-calf pair was based on actual weight information (after 2012 season) and the goal of building even more conservatism into our program.

2013 Animal Units (PBG Unit 5)

Animal Type	Number	Actual weights	AU per type	Actual AU
Heifers	34	900	0.92	31.28
Bull Mature	2	1600	1.6	3.2
Totals	36			**34.48**

Stocking Rate Calculations

Using Utah State Extension cow/calf pair multiplier of 1.5

2012 (units 1-5): 1,969 ac., 260.4 AU, 3.9 mo. = **1.9 ac./AU/mo. = 0.52 AUMs/acre**

2013 (units 1-4): 1,611 ac., 157.9 AU, 3.57 mo. = **2.9 ac./AU/mo. = 0.35 AUMs/acre**

2013 (unit 5): 90 acres, 34.48 AU, 3.57 mo. = **0.7 ac./AU/mo. = 1.37 AUMs/acre**

Using adjusted cow/calf pair multiplier of 1.8 based on actual weights measured in 2012

2012 (units 1-5): 1,969 ac., 292 AU, 3.9 mo. = **1.7 ac./AU/mo. = 0.58 AUMs/acre**

2013 (units 1-4): 1,611 ac., 188.2 AU, 3.57 mo. = **2.4 ac./AU/mo. = 0.42 AUMs/acre**

2013 (unit 5): 90 ac., 34.48 AU, 3.57 mo. = **0.7 acres/AU/mo. = 1.37 AUMs/acre**

Table 3: Pooled taxa

- *Apocynum* sp.: *A. cannabinum, A. sibiricum*
- *Asclepias ovalifolia/syriaca: A. ovalifolia, A. syriaca*
- *Carex* sp.: *C. bicknellii, Carex brevior, C. inops, C. meadii, C. praegracilis, C. tetanica*
- *Cirsium altissimum/discolor: C. altissimum, C. discolor*
- *Lactuca* sp.: *L. canadensis, L. serriola*
- *Melilotus* sp.: *M. officinalis, M. alba*
- *Muhlenbergia* sp.: *M. mexicana, M. racemosa, Muhlenbergia* seedlings
- *Oxalis* sp.: *O. stricta, O. violacea*
- *Physalis* sp.: *P. heterophylla, P. virginiana*
- *Setaria* sp.: *S. glauca, S. viridis*

Results and Discussion

After consolidating several taxa into groups, a total of 150 species and species groups were recorded within the project area in 2011 and 2013 (Appendix A). Several species that are among the most dominant in units 1-4, including porcupine grass, Missouri goldenrod, and leadplant, are absent or nearly absent from Unit 5, which has a recent history of past overgrazing. Other species associated with highly overgrazed sites are more abundant in unit 5, including wolfberry, Canada goldenrod, white clover, quackgrass, and Canada thistle. The overall species richness of unit 5 is significantly lower ($p<0.05$) than that of the other management units.

Vegetation Structure

A measure of vegetation structure was obtained by recording Visual Obstruction Readings (VOR), following the procedure of Robel et al. (1970). At the start of sampling in each plot, a tall pole calibrated with markings for every decimeter (10cm) and half decimeter was held at the center of the plot. Four readings were taken, one for each cardinal direction, at a distance of 4m from the pole with the reader's eye at 1m above the ground. Each reading corresponded to the lowest half-decimeter mark visible on the pole. The four measurements were then averaged to calculate a mean VOR for each plot. Thus, a high VOR reading corresponds to taller vegetation. With the exception of sweet clover infestations, VOR readings in this site were determined primarily by the height of grasses. Plots with a uniform tall sward of grass typically had four, high mean VOR readings, whereas partially-grazed plots with a mix of grazed and ungrazed patches had lower mean VOR readings and greater variation among readings.

Mean VOR decreased dramatically in unit 1 from 2011 to 2013, reflecting the absence of the dense sweet clover present in 2011 from the 2010 burn (Figure 2). Less change in mean VOR was observed between 2011 and 2013 in units 2 and 3. Unit 4 showed reduction in mean VOR in grazed plots from 2011 to 2013, in contrast to an increase in exclosure plots, which correlates with the greater amount of grazing in that unit in 2013 compared to other units.

Unit 5 showed a dramatic increase in VOR from 2011 to 2013 within the exclosures, reflecting the dense growth of sweet clover in response to the 2012 burn. In 2013, approximately 90 acres of unit 5 were fenced off with temporary fencing and grazed with heifers and bulls at a much heavier stocking rate than other parts of the project area (1.37 AUMs/acre for this 90 acre area versus 0.35-0.42 AUMs/acre for units 1-4). This was to examine the effects of two years in a row of focused grazing on sweet clover ("double grazing"). Single-grazed plots had a reduced increase in mean VOR compared to exclosures, whereas double-grazed plots had a significant reduction in mean VOR compared to the pre-grazing (2011) condition (Figure 3).

Dense sweet clover thickets forming in the second summer after a burn suppress aboveground biomass and cover of other plants, such as dominant warm season grasses like big bluestem. This was clearly demonstrated in comparison of photographs of unit 5 exclosures from 2012 (heavy big bluestem) with 2013 (heavy sweet clover) (Figure 4). Short-lived sweet clover thickets do not appear to affect plant species richness after the sweet clover thicket has abated (pers. obs.), though we do not yet have a full set of pre- and post- sweet clover thicket data.

Analysis-of-deviance indicates statistically significant differences in the change from 2011 to 2013 in mean VOR (ΔVOR) among years, management units, and grazed vs. exclosure plots. Overall, mean VOR was approximately 2 dm lower (p=0.004592) in grazed plots (all management units) compared to exclosure plots in 2013.

Figure 5 graphically illustrates the differences in ΔVOR between grazed and exclosure plots, with each relative to a starting point of 0 in 2011. Arrows on the X axis indicate years in which a controlled burn (red arrow) and grazing (green arrow) took place. In unit 1, there was a greater reduction in mean VOR in grazed plots than in exclosures. In units 2-4, mean VOR increased in exclosures but decreased in grazed plots. In unit 5, exclosure plots increased in mean VOR, single-grazed plots (unit 5a) increased in mean VOR but had a lower increase in mean VOR than exclosures, and mean VOR decreased in double-grazed plots (unit 5b).

These data suggest that the VOR data captured the pulses of more concentrated grazing within the burn units, as well as lower levels of grazing in other units.

Figure 2: Average Visual Obstruction Reading in 2011 and 2013 in Grazed and Exclosure Plots (error bars are standard errors).

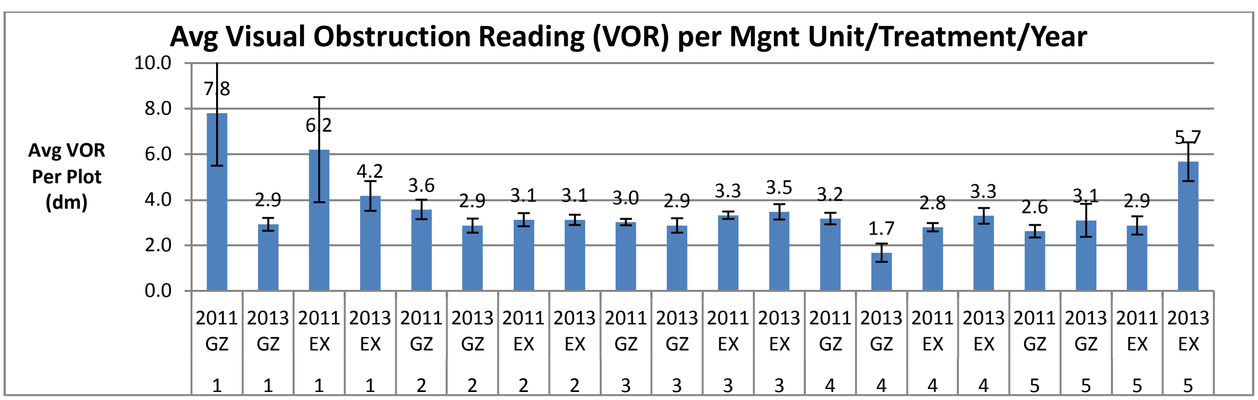
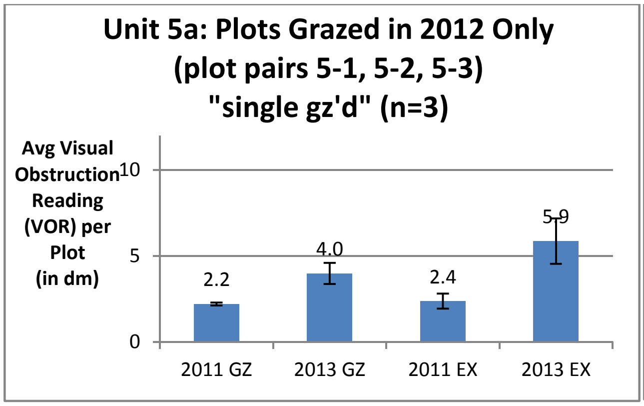


Figure 3: Vegetation structure in single-grazed (2012) versus double-grazed (2012 & 2013) plots at Unit 5 with dense sweet clover in 2013 following spring 2012 burn (error bars are standard errors). Note that the data from the grazed (GZ) plots in 2011 reflect the pre-grazing conditions.



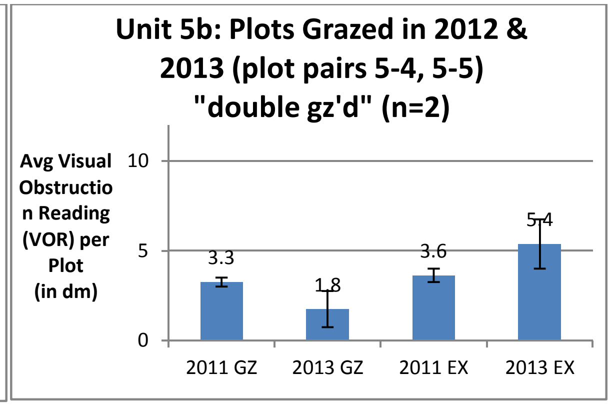
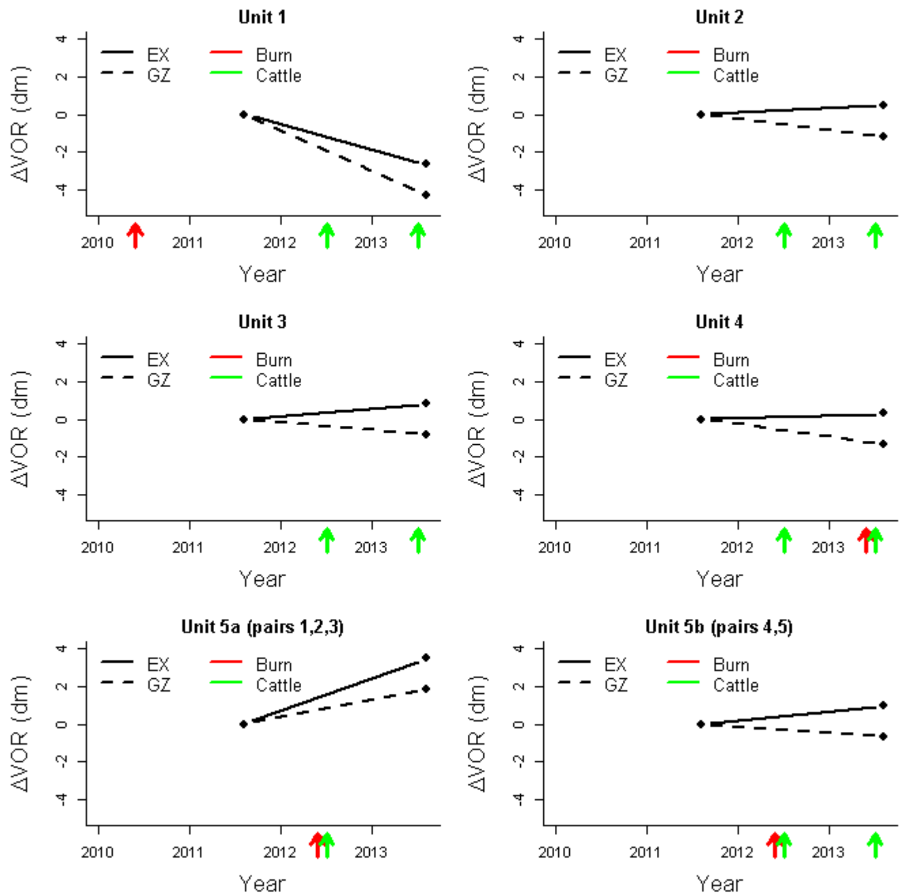


Figure 4: photos of unit 5 exclosures in late July/early August 2012 (a) and in 2013 (b). (This may not be the same exclosure in both years).

a: 2012

b: 2013

Figure 5: Comparison of ΔVOR between grazed and exclosure plots within management units:



Species Richness

In management units 1-4, we observed little change in mean total, native, and exotic species richness for each unit/treatment/year combination from 2011 to 2013 (Figure 6). The largest change in mean total, native, and exotic species richness per plot from 2011 to 2013 occurred within the grazed plots of unit 5, which were the most heavily grazed plots in the project to date. The observed increase in mean total species richness in grazed plots from 2011 to 2013 is due to increases in both exotic and native species richness. All unit 5 plots were grazed in 2012. In 2013 unit 5 was fenced off from the rest of the project, but two of the 5 plot pairs were grazed within a 90-acre portion of the unit fenced off with temporary fencing – these two plots are labeled unit 5b.

The change in mean number of native species (ΔNR) per plot varied by year and unit ($p=0.008$) but not plot type (exclosure vs grazed) ($p>0.725$). The only statistically significant difference in ΔNR between grazed and ungrazed plots was in unit 5b ($p = 0.03$). Figure 7 graphically shows shows ΔNR from 2011 to 2013 in each of the management units.

The change in mean exotic species richness (ΔER) varied by year, unit and plot type ($p=0.002$). Compared to exclosure plots, the mean number of exotic species was greater in grazed plots in units 2, 4, and 5, but lower in units 1 and 3. The greatest differences in ΔER between grazed and ungrazed plots occurred in unit 5 (unit 5a: $p=0.0002$; unit 5b: $p = 0.035$). The largest differences in ΔER between grazed and ungrazed plots were in unit 5a, which had the three "single-grazed" plots grazed only in 2012 and not in 2013. Figure 8 gives a graphical representation of ΔER for grazed and exclosure plots within each management unit, each relative to a starting point of 0 in 2011.

Table 4 lists the plant species that account for the change in species richness in the grazed plots of unit 5. Some of the species recorded in only one year were recorded in only a few quadrats.

Increasing plant species richness with light to moderate grazing has been demonstrated in many vegetation studies of the effects of grazing management (Symstad et al. 2011). The native species appearing in 2013 for the first time in unit 5 are mostly species with well-known tolerance for grazing. Future sampling will determine if this trend of increasing species richness continues in grazed plots, whether grazed plots reveal a different pattern than exclosure plots, and the extent to which increases in richness are accounted for by native versus exotic species.

Figure 6: Mean exotic (invasive), native, and total species richness per plot versus year and treatment (error bars are standard errors).

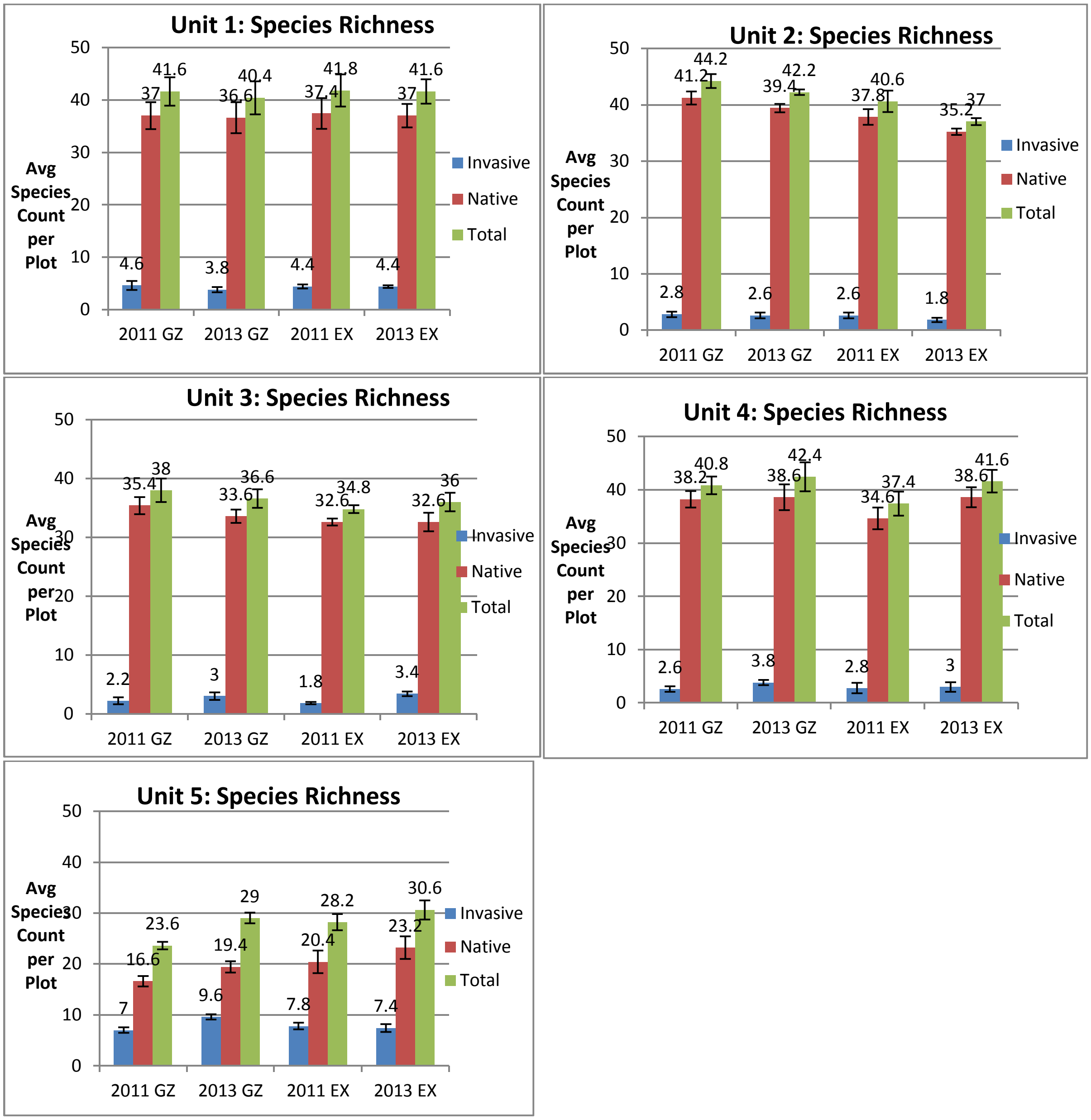


Table 4: Species accounting for changes in species richness of grazed plots from 2011 to 2013 in Unit 5:

Species seen in only 1 year in Unit 5 Grazed Plots	Life Form	2011	2013
Common ragweed (*Ambrosia artemisiifolia*)	NF		X
Leadplant (*Amorpha canescens*)	S	X	
False indigo (*Amorpha nana*)	S	X	
Thimbleweed (*Anemone cylindrica*)	NF	X	
Dogbane (*Apocynum sp.*)	NF	X	
Swamp milkweed (*Asclepias incarnata*)	NF		X
Tall thistle (*Cirsium altissimum/discolor*)	NF		X
Porcupine grass (*Hesperostipa spartea*)	CSG	X	
Rough bugleweed (*Lycopus asper*)	NF		X
Evening primrose (*Oenothera biennis*)	NF		X
W wheatgrass (*Pascopyrum smithii*)	CSG		X
Wild plum (*Prunus americana*)	S	X	
Miss. goldenrod (*Solidago missouriensis*)	NF		X
Stiff goldenrod (*Solidago rigida*)	NF		X
Goatsbeard (*Tragopogon dubius*)	EF		X
Red clover (*Trifolium pratense*)	EF		X
White clover (*Trifolium repens*)	EF		X
Blue vervain (*Verbena hastata*)	NF		X
Hoary vervain (*Verbena stricta*)	NF		X

Figure 7: ΔNR from 2011 to 2013 for the 5 Management Units (ΔNR was not significantly different between grazed and exclosure plots):

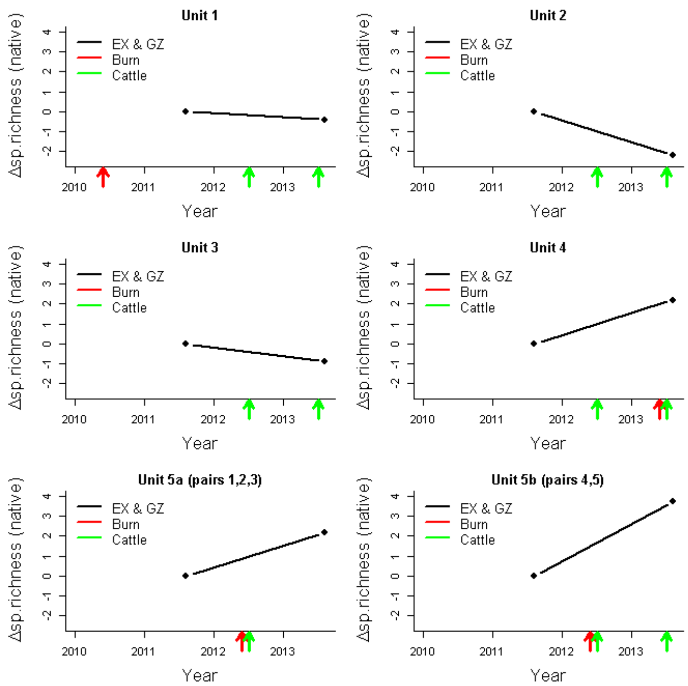
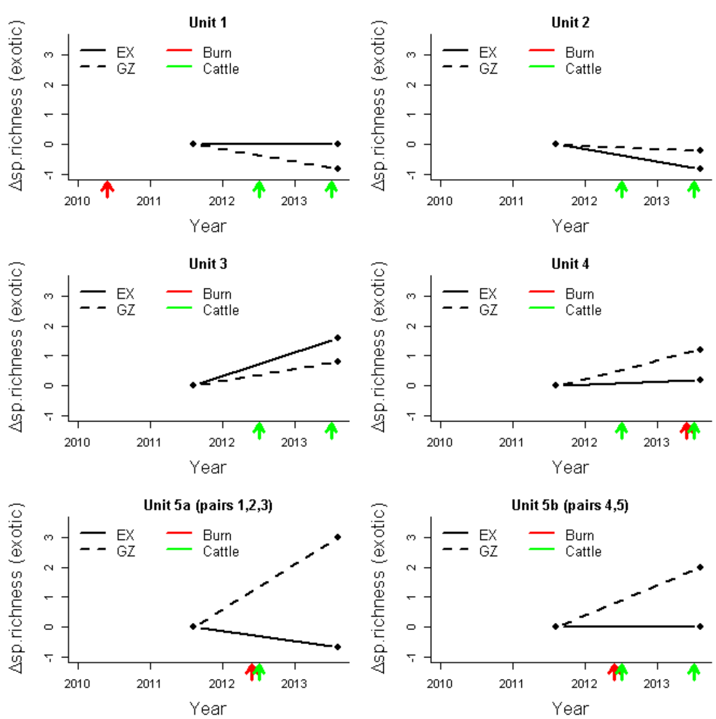


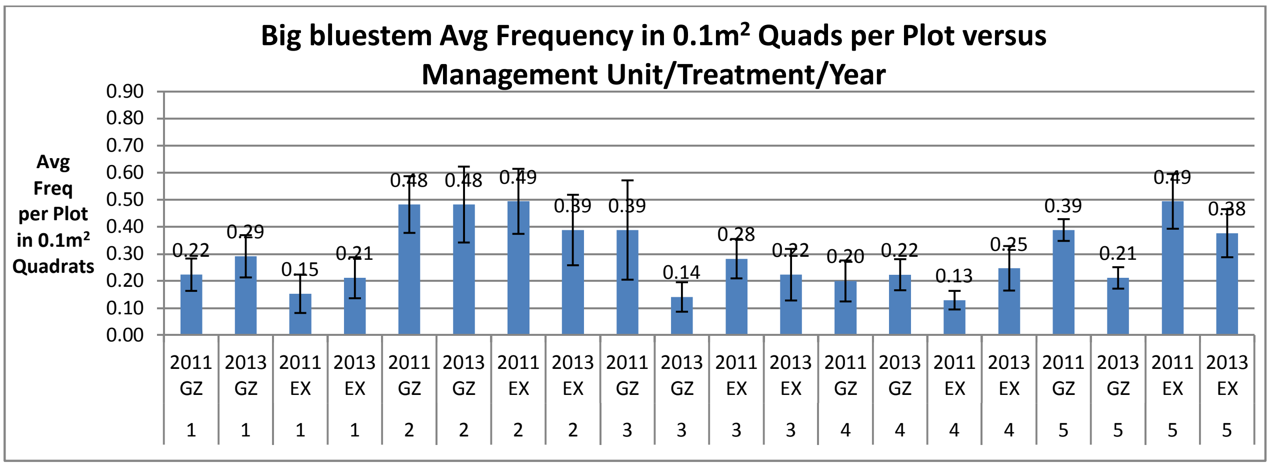
Figure 8: Comparison of the Change in Exotic Species Richness (ΔER) between grazed and exclosure plots within management units:

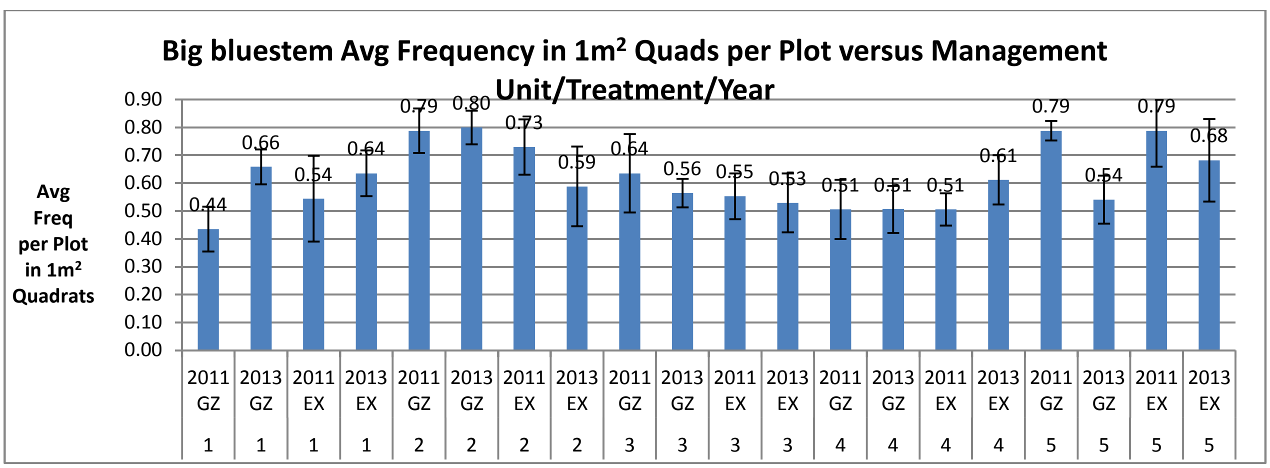


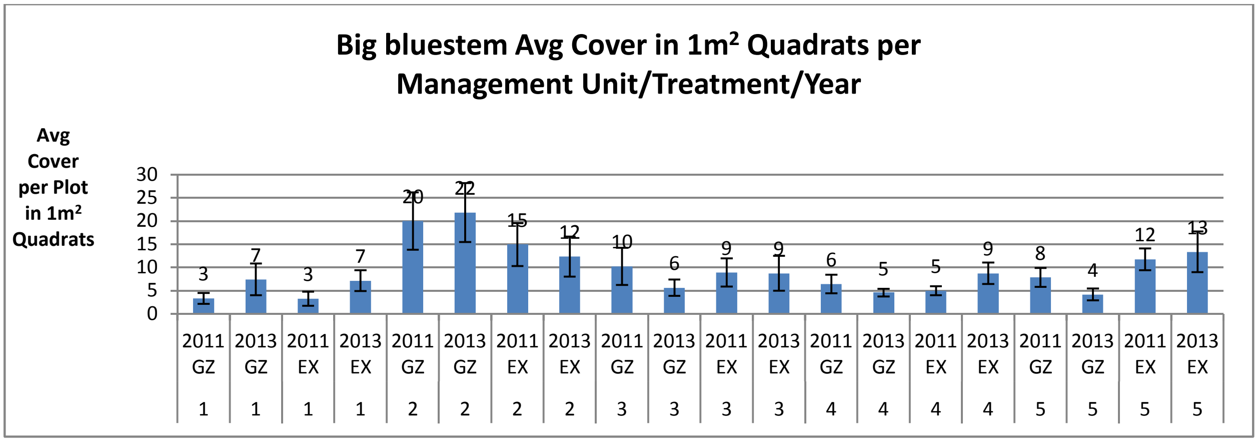
Big Bluestem

Little change in mean frequency or cover per plot of big bluestem was observed between combinations of unit/treatment/year (Figure 9). Photos of exclosures in unit 5 late in the 2012 season showed a dense sward of big bluestem stimulated by the 2012 burn that was not present in 2013 because of dense sweet clover (Figure 4). If sweet clover had not formed such a dense thicket in 2013, it is likely that the unit 5 exclosures would have had much higher cover of big bluestem in 2013. Many other warm season grasses are co-dominant or more abundant than big bluestem in units 1-4, where total warm season grass cover is very high, whereas big bluestem was the main warm season grass present in unit 5 (Appendix A).

Figure 9: Big bluestem average frequency and cover per plot versus year and treatment for each management unit (error bars are standard errors).





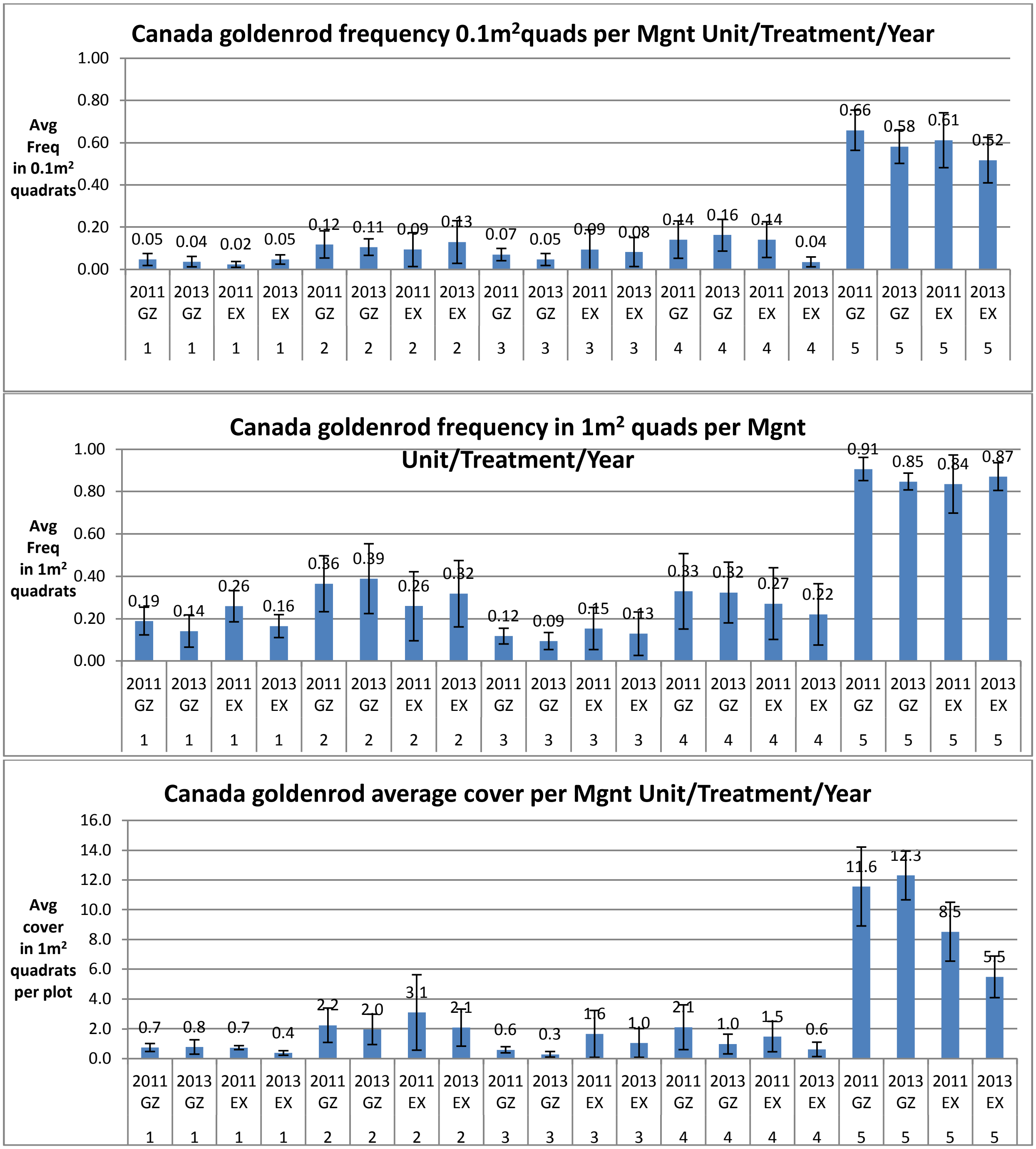


Canada goldenrod

Canada goldenrod, which consists of plants from one or both of two closely related species that were not separated in the field (*Solidago altissimum* ssp *gilvocanescens* and *Solidago canadensis*), is the predominant goldenrod in unit 5, occupying over 80% of 1-m^2 quadrats (Appendix A). Unit 5 has a recent history of overgrazing and is significantly more degraded than other units in the project area. The frequency and cover of Canada goldenrod did not change much from 2011 to 2013 in grazed and exclosure plots at Chippewa Prairie (Figure 10).

Managers were interested in determining if an apparent superabundance of Canada goldenrod in grazed relative to ungrazed prairie in unit 5 reflected an actual short-term increase in response to grazing or a temporary reduction of other species that hide goldenrod, particularly big bluestem, as a result of grazing. In addition, Canada goldenrod was highly abundant in unit 5 in 2012 and 2013 because the cattle avoided it. Our data show that Canada goldenrod is highly abundant in unit 5 because of its previous land use history and not because of the grazing that took place in 2012 and 2013. Other goldenrod species, Missouri goldenrod (*S. missouriensis*), gray goldenrod (*S. nemoralis*), stiff goldenrod (*S. rigidus*), and showy goldenrod (*S. speciosa*) are all very infrequent in unit 5 and much more abundant in units 1-4 (Appendix A). Of these, the showy goldenrod, a non-rhizomatous species, is much less likely to increase with grazing.

Figure 10: Frequency and percent cover of Canada goldenrod (*Solidago altissimum* ssp *gilvocanescens* and/or *Solidago canadensis*) in grazed and exclosure plots in Unit 5 in 2011 and 2013 (error bars are standard errors).



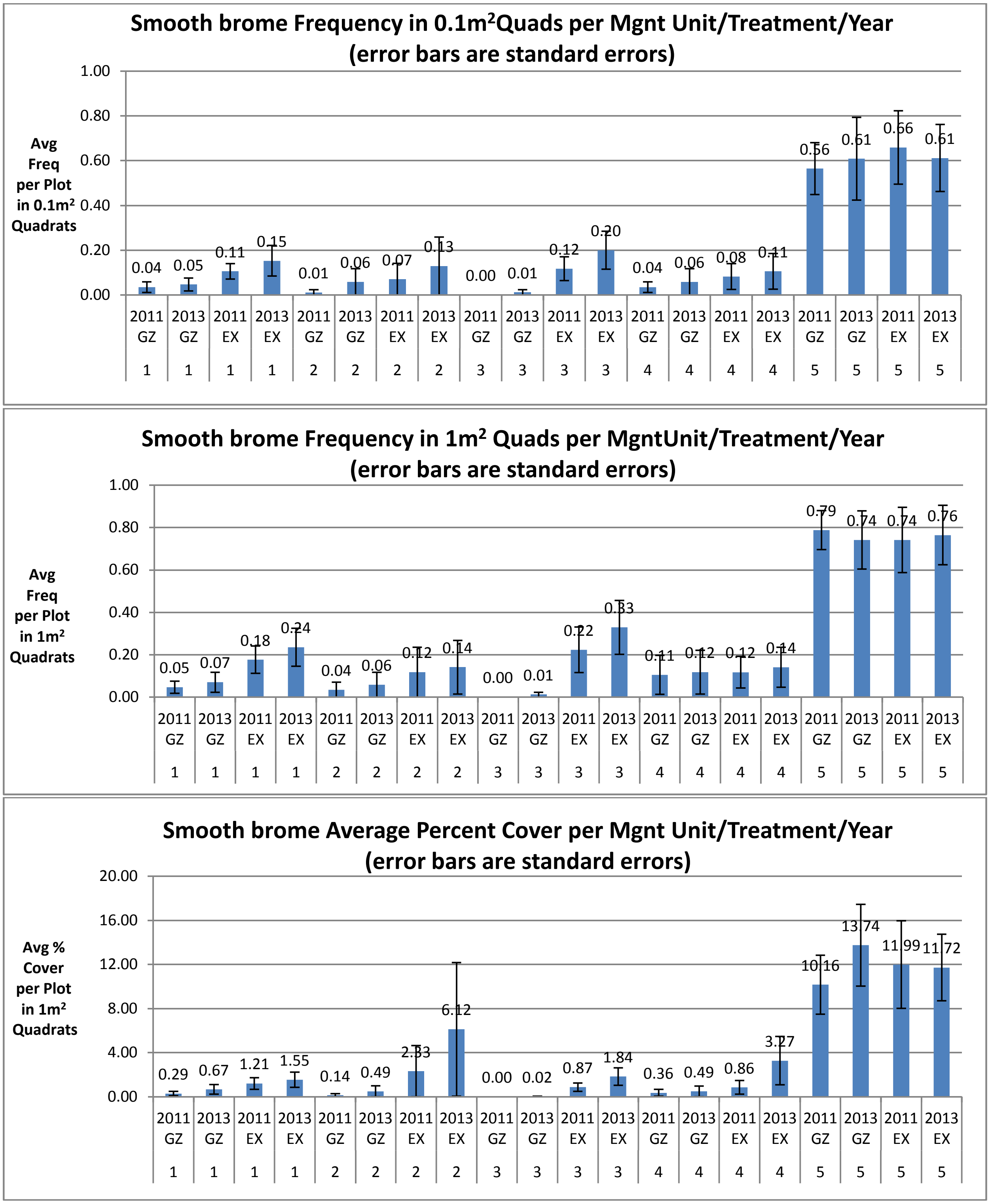
Smooth brome

In units 1-4, smooth brome was recorded at least once in fifteen 10-m x 10-m plots in 2011 and at least once in eighteen plots in 2013, thus appearing for the first time in three plots in 2013. Smooth brome is present in all unit 5 plots. The mean frequency and percent cover of smooth brome slightly increased from 2011 to 2013 in nearly every management unit/treatment/ year combination (Figure 11). No significant trend was detected in 1-m^2 brome cover (LRT test, df = 3, 26; Chisq = 23.83; p = 0.124) or frequency (LRT, df = 3, 26; Chisq = 30.967; p = 0.413) using the mixed-model approach. Though there were large differences in the frequency and cover of smooth brome among different management units, the changes within management units from 2011 to 2013 in brome cover and frequency had a relatively small range and did not vary much among units.

Future monitoring will reveal if smooth brome is increasing in cover across the project area. The years 2012 and 2013 had extended, moist, cool springs which created very favorable conditions for the growth and expansion of cool season grasses like smooth brome. Currently the project has areas of dense smooth brome in formerly cultivated fields and along the perimeters, such as near township and county roads, and adjacent pastures. Bordering these high density zones are areas of scattered, circular clones of smooth brome – these scattered clones are visible in color infra-red photography. Other, interior portions of the project area completely lack smooth brome at this time. Analysis of multi-spectral imagery of the site from several years that can map the extent of smooth brome in the project area may enable us to quantify the extent of smooth brome within the project area in different years.

Other exotic cool season grasses are present. Across the project area, Kentucky bluegrass (*Poa pratensis*) is one of the most frequently-encountered species but is not a vegetative dominant. Unlike smooth brome, this species is so difficult to visually estimate cover that cover measurements are virtually meaningless. Kentucky bluegrass is likely present in every mesic prairie remaining in Minnesota: in most cases it is very sparse and kept in control by fire management; it tends to be highly abundant and problematic in mesic sites that have a history of overgrazing.

Figure 11: Smooth brome Average Frequency and Cover in All Units (error bars are standard errors).



Next Steps

Because unit 5 was removed from the pbg project in 2013, our first opportunity to observe grazing in a patch during the second summer after a burn will be 2014. If unit 3 is burned in 2014 as planned, we expect this unit to be the most heavily grazed, followed by unit 4. If a low availability of water was a reason that cows spent less time than expected on the burn patch (unit 4) in 2013, then in 2014 the new well on the east side of units 3 and 4 will likely promote greater grazing of the unit 3 burn patch and the adjacent 2nd year patch (unit 4).

In 2013, we observed that cattle congregated in some wet swales where they churned up the ground surface leaving bare soils (Dana 2013). This raised concerns that these areas would be invaded by exotic species, thus resulting in a conversion of wet prairie dominated by native species to a community dominated by invasive species. We do not know how many wet swales had this happen. We also do not know if in fact these places will be taken over by invasive species. In 2014, we plan to establish additional vegetation transects within these places to track the vegetation. This should include relatively undisturbed, native swales within portions of the project area that have not yet had the focused burn-graze treatment.

Unit 5 presently has highly degraded vegetation due to overgrazing that took place before the unit was acquired as a WMA. The site is dominated by non-native species; conservative, grazing decreaser plant species are mostly absent; and species that indicate severe disturbance are abundant such as absinthe wormwood (*Artemisia absinthium*). As indicated in exclosures, the 2012 controlled burn stimulated increased production of big bluestem (Figure 4). For the near future, managers should consider managing this unit to bring back more of the native prairie, such as more frequent controlled burns without grazing, or burns with grazing limited to short term intensive periods timed to set back the dominant smooth brome. Controlling brome with targeted grazing is promoted by some prairie managers, though I have not found this to be documented in the literature. Some studies found increases in smooth brome with light to moderate grazing (not targeted) compared to controls (e.g. Brudvig et al. 2007, where grazing was 3-4 weeks/year at different times of year).

We need to explore ways to make the vegetation sampling process faster and more efficient. Over the winter, we will test the existing data using only 12 quadrats per plot instead of 17 to see if there is much difference in species detected and statistical power. Also, we will consider dropping the measurement of cover and only recording the presence/absence of species rooted within nested quadrats. Visual estimation of cover is more prone to inconsistency by different observers, as well as being more affected by conditions at the time of sampling. Estimating cover is very problematic in plots where recent grazing has clipped off the aboveground plant biomass. If we can increase the efficiency of vegetation sampling, then we should consider sampling every year instead of every other year to increase the power of our study design to detect pulse-type responses to pbg treatments. The current approach (sampling every other year) captures the focused burn unit-grazing effect only half the time (half the units) and the 2nd year post-grazing effect only half the time (half the units).

Appendix A

Taxa, life form, and number of plots present per management unit and year.

Part 1: Taxa recorded in at least 3 plots

		Life	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
Scientific Name	**Common Name**	**Form***	**2011**	**2013**	**2011**	**2013**	**2011**	**2013**	**2011**	**2013**	**2011**	**2013**
Achillea millefolium	yarrow	NF	5	4	6	7	5	3	6	5	6	6
Agrostis gigantea	redtop	ECG									7	3
Agrostis scabra	rough bentgrass	NCG			2			1				
Allium stellatum	prairie wild onion	NF	4	4	3	3	3	3	7	6	3	2
Ambrosia artemisiifolia	common ragweed	NF		2			1					5
Ambrosia psilostachya	western ragweed	NF	8	7	10	10	5	5	6	6	3	7
Amorpha canescens	leadplant	S	7	7	10	10	6	6	8	10	1	
Amorpha nana	false indigo	S	2	3	1	1	3	2	2		1	
Andropogon gerardii	big bluestem	WG	9	10	10	10	10	10	10	10	10	10
Anemone canadensis	Canada anemone	NF	4	6	3	4	4	6		4		
Anemone cylindrica	thimbleweed	NF	8	9	8	10	10	10	9	9	2	
Anemone patens	pasqueflower	NF	4	3	7	5	6	6	6	5		
Antennaria neglecta	common pussytoes	NF	2	1	1		1	1	2	6		
Apocynum	dogbane	NF	4	5			2	1			5	3
Artemisia ludoviciana	white sage	NF	7	7	8	8	9	7	9	10	1	1
Asclepias syriaca/ovalifolia	common/ovalleaf milkweed	NF	5	6	1	2	1	4	4	5	9	9
Asclepias verticillata	whorled milkweed	NF	2				1	3	1	3	5	7
Astragalus canadensis	Canada milkvetch	NF		2	1	2	1	1	4	3		
Astragalus crassicarpus	prairie plum	NF		2	1	1	1	2				
Bouteloua curtipendula	sideoats grama	WG	10	10	10	10	10	10	10	10	8	9
Bromus inermis	smooth brome	ECG	6	6	2	3	3	5	4	4	10	10
Calylophus serrulatus	toothed-leaved evening primrose	NF	3	3	5	3	4	3	3	1		
Calystegia sepium	hedge bindweed	NC	1	1			1	1	1	2		
Carex	sedge	NS	10	10	10	10	9	10	10	10	9	9
Chenopodium pratericola	desert goosefoot	NF				2				2		
Cirsium altissimum/discolor	tall/field thistle	NF	4	2	1	1	3	3	2	4		3
Cirsium arvense	Canada thistle	EF	2	1							7	9
Cirsium flodmanii	Flodman's thistle	NF	6	6			1	1	1	3	6	6
Cirsium vulgare	bull thistle	EF									2	1
Cornus sericea	red osier dogwood	S									3	2
Dalea candida var. *candida*	white prairie clover	NF	8	9	10	10	6	6	10	10		
Dalea purpurea	purple prairie clover	NF	5	4	10	10	8	7	8	9	1	1
Dichanthelium leibergii	Leiberg's panic grass	WG	7	5	5	5	3	3	4	2		1
Dichanthelium oligosanthes	Scribner's panic grass	WG	9	7	10	10	6	5	7	9	2	5
Dichanthelium ovale	long-haired panic grass	WG	4	4	8	6	6	5	8	3		
Echinacea angustifolia	pale purple coneflower	NF	2	4	3	4	3	4	3	2		
Elymus repens	quackgrass	ECG	3	2					3	3	9	9
Elymus trachycaulus	slender wheatgrass	NCG	10	7	9	1	10	9	9	10	2	3
Erigeron strigosus	daisy fleabane	NF			2		2		1			
Fragaria virginiana	wild strawberry	NC	1	1		1					1	1
Galium boreale	northern bedstraw	NF	4	4	1	1						
Gentiana puberulenta	downy gentian	NF	2	2	4	4	2	1	4	4		
Geum triflorum	prairie smoke	NF	1	2	1							
Helianthus maximiliani	Maximilian sunflower	NF	2		1	1					3	3
Helianthus pauciflorus	stiff sunflower	NF	9	8	9	10	7	9	7	7		
Heliopsis helianthoides	ox-eye	NF	3	2								
Hesperostipa spartea	porcupine grass	NCG	10	10	10	10	10	10	10	10	1	2
Heuchera richardsonii	alumroot	NF	2	7	5	6	5	6	3	6		
Koeleria macrantha	Junegrass	NCG	5	1	8		6		6			
Lactuca	wild lettuce	NF/EF	5				4		2			
Liatris aspera	rough blazingstar	NF	8	9	9	10	10	10	10	10		

Linum sulcatum	grooved yellow flax	NF	5		6	2		2	7	4		
Lithospermum canescens	hoary puccoon	NF	2	2	8	10	7	8	8	9		
Lotus purshianus	prairie trefoil	NF	3	3			1	1				
Medicago lupulina	black medick	EF		5		1		1		3	9	10
Melilotus	sweet clover	EF	9	9	7	4	2	4	2	4	6	10
Mirabilis albida	hairy four o'clock	NF							2	2		
Monarda fistulosa	wild bergamot	NF	4	3	1			1				
Muhlenbergia	muhly grass	WG	2	2	2	3	1	1	1		1	
Muhlenbergia cuspidata	plains muhly	WG	2		3	1			1	1		1
Oenothera biennis	common evening primrose	NF			1				1			2
Onosmodium molle	false gromwell	NF			1	1	2	2	2	5	2	2
Oxalis	wood sorrel	NF	4	2	7	3	3		6	9	2	6
Panicum virgatum	switchgrass	WG	3	3	5	7	6	8	5	7	7	6
Parthenocissus vitacea	woodbine	NC									2	2
Pascopyrum smithii	western wheatgrass	NCG		1								3
Pediomelum argophyllum	silver-leaved scurfpea	NF	9	9	4	5	6	6	4	5		
Pediomelum esculentum	prairie turnip	NF	1	3		3	3	6	1	3		
Phalaris arundinacea	reed canarygrass	ECG			1	1					1	1
Phleum pratense	timothy	ECG		1							1	1
Phlox pilosa	prairie phlox	NF	6	6								
Physalis	groundcherry	NF	5	8	10	10	9	9	7	10	1	1
Poa compressa	Canada bluegrass	ECG			4				2	3		
Poa pratensis	Kentucky bluegrass	ECG	10	10	10	10	10	10	10	10	10	10
Polygala verticillata	whorled milkwort	NF			2	1			2	8		
Potentilla arguta	tall cinquefoil	NF	4	4	3	6	1	2				
Prunus americana	wild plum	S	4	4					1	1	3	3
Ratibida columnifera	yellow coneflower	NF			2	2	1		1			
Rosa arkansana	prairie rose	S	10	10	9	9	6	5	8	8	3	4
Schizachyrium scoparium	little bluestem	WG	10	8	9	10	10	10	10	10	8	10
Scutellaria leonardii	Leonard's skullcap	NF	1	1						1		
Setaria	a species of foxtail	ECG	1			1				2		
Sisyrinchium campestre	field blue-eyed grass	NF	2		7	1	3	1	3	7	1	
Solidago canadensis/S. altissima ssp *gilvocanescens*	Canada goldenrod	NF	9	8	8	9	7	5	10	8	10	10
Solidago missouriensis	Missouri goldenrod	NF	10	9	10	10	10	10	9	9		4
Solidago nemoralis	gray goldenrod	NF			2	1	4		6			
Solidago rigida	stiff goldenrod	NF	10	10	10	10	10	10	7	8	3	4
Solidago speciosa	showy goldenrod	NF		2	6	6	3	3	2	3		1
Sonchus arvensis	sow thistle	EF					1	4			3	3
Sorghastrum nutans	Indian grass	WG	8	6	7	7	6	5	8	8	7	8
Spartina pectinata	cordgrass	WG									3	3
Spiraea alba	white meadowsweet	S	1	1	1	1	2	3	6	6		
Sporobolus compositus	tall dropseed	WG		3		1					4	3
Sporobolus heterolepis	prairie dropseed	WG	10	9	8	10	8	8	9	10	5	4
Symphoricarpos occidentalis	wolfberry	S	2	2	6	6	4	4	2	2	9	8
Symphyotrichum ericoides	heath aster	NF	10	10	10	10	10	9	10	10	9	8
Symphyotrichum lanceolatum	lance-leaved aster	NF	4	3	2	2	2	1	4	3	5	5
Symphyotrichum oblongifolium	aromatic aster	NF	2	7	7	7		3				
Symphyotrichum sericeum	silky aster	NF	8	9	10	10	10	10	8	8		
Taraxacum officinale	dandilion	EF	3	6			2	3	2	1	5	8
Thalictrum dasycarpum	tall meadow-rue	NF	5	5	1	1	1					
Tragopogon dubius	goatsbeard	EF	2		3	2	2	5	1	3		1
Trifolium pratense	red clover	EF	2									2
Trifolium repens	white clover	EF							1		3	5
Verbena stricta	hoary vervain	NF		1			2	1		2		2
Viola palmata var. *pedatifida*	prairie birdsfoot violet	NF	10	10	10	10	10	10	10	10	10	10
Zizia aptera	heart-leaved alexanders	NF	5	6	6	5	6	6	6	7	3	2
Zizia aurea	golden alexanders	NF	1	1	1		2	1				

Part 2: Taxa Recorded in 2 or Fewer Plots

Scientific Name	Common Name	Life Form*	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
			2011	2013	2011	2013	2011	2013	2011	2013	2011	2013
Agoseris glauca	prairie false dandilion	NF						1				
Arabis	rockcress	NF			1							
Asclepias incarnata	swamp milkweed	NF										1
Asclepias viridiflora	green milkweed	NF		1		1						
Bouteloua gracilis	blue grama	WG			1					1		
Conyza canadensis	horseweed	EF	1							1		
Dactylis glomerata	orchard grass	ECG										1
Delphinium carolinianum ssp. *virescens*	prairie larkspur	NF						1		1		
Dichanthelium linearifolium	linear-leaved panic grass	WG							1			
Gentiana andrewsii	bottle gentian	NF						1				
Glycyrrhiza lepidota	wild licorice	NF									1	1
Helianthus tuberosus	Jerusalem artichoke	NF								1		
Lobelia spicata	pale-spiked lobelia	NF							1	1		
Lycopus asper	rough bugleweed	NF										1
Oxytropis lambertii	Lambert's locoweed	NF							1			
Packera plattensis	prairie ragwort	NF						1				
Penstemon gracilis	slender penstemon	NF			1	1						
Polygala senega	senega snakeroot	NF								2		
Potentilla norvegica	rough cinquefoil	EF									1	
Prenanthes racemosa	smooth rattlesnakeroot	NF	1				1					
Pycnanthemum virginianum	mountain mint	NF	2									
Rumex crispus	curly dock	EF									1	1
Solidago gigantea	giant goldenrod	NF			1						1	
Stellaria	chickweed	EF							2			
Strophostyles leiosperma	trailing pea	NF					1		1			
Symphyotrichum laeve	smooth aster	NF						1				1
Ulmus pumila	Siberian elm	T	1									
Verbena hastata	blue vervain	NF										2
Vitis riparia	wild grape	NC									2	

*Life Form:
ECG: exotic cool season grass
EF: exotic forb
NC: native climber
NCG: native cool season grass
NF: native forb
NS: native sedge
S: native shrub
T: tree
WG: warm season grass

Appendix B: Statistical Analysis

Report from John Giudice, Ph.D.
Statistician
Division of Fish and Wildlife
Minnesota DNR

With only 2 years of data, it is not possible to fit the full ANOVA model described in Harris (2013). Therefore, I fit a simpler model for the purposes of this progress report (i.e., to illustrate the type of analysis and inference that we hope to use when we have more data). Because we are primarily interested in change over time and each plot has different starting values, the response metric in this case will be $\Delta Y = Y_{ij} - Y_{i,2011}$, where i = plot and j = year. Essentially this uses the measurements from 2011 as base values and the focus becomes modeling relative change over time using a common starting point (= 0). This can also be accomplished using a model offset term (which should be explored in future analyses that have more data). I then fit linear mixed models using ΔY as the response and year, unit, and plot-type as categorical fixed effects. To account for the repeated measurements on each plot (over time), I used 'pairs' as a random effect. Ideally we would use plot ID (subject) as the random effect, but we need more data to estimate a random variance term at the subject level. Initially, I tried to fit a model that included all possible interactions involving the 3 categorical predictors (unit, year, plot type) because the plot-type:unit:year interaction is our best test of the pbg treatment effect. In other words, we would expect the effect of plot type (exclosure vs. grazing) to vary as a function of year and unit because prescribed fire treatments and associated intensive grazing (in theory) are staggered over space and time. However, we only have 2 years of data at this point and we are modeling relative change in Y. Furthermore, we also have a low-intensity level of background grazing that may result in more subtle changes over time. Thus, significant interactions involving plot-type:year or plot-type:unit may also be informative in this analysis. I fit the linear mixed models using the R programming language (R Core Team 2013) and packages lme4 (Bates et al. 2013) and lmerTest (Kuznetsova et al. 2013). I used analysis-of-deviance and t tables (lmerTest) to evaluate the importance of predictors (especially the plot-type:unit:year interaction). If the plot-type:unit:year interaction was not strongly supported by the data, then I fit and evaluated (likelihood ratio tests and information criteria) reduced models to estimate the magnitude of relative change in Y over time and whether it varied by unit, year, or plot type. Model-based estimates of mean relative change are presented graphically for response metrics that had significant covariate terms. However, 2 years of data is not sufficient for assessing management impacts on systems composed primarily of long-lived, perennial plants. Therefore, all vegetation sampling results must be seen as preliminary.

Finally, I focused on a relatively simple subset of response metrics for this report, which was sufficient given our data limitations at this point. However, ultimately we would also like to quantify temporal trends in species assemblages (e.g., Gotelli et al. 2010) or other multivariate metrics. The later type of analyses will require more data and years. In the interim, we will work on developing an analysis plan for these multivariate data.

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