ROCKY MOUNTAIN NATIONAL PARK
2010 RESTORATION MONITORING REPORT

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EFFECTS OF IMAZAPIC APPLICATION ON CHEATGRASS AND NATIVE PLANT SPECIES IN ROCKY MOUNTAIN NATIONAL PARK

ABSTRACT

Cheatgrass (*Bromus tectorum*) has been a major invasive weed in the Western United States for nearly a century, and has more recently become a threat to the montane and subalpine ecosystems of Rocky Mountain National Park (RMNP). Imazapic is an herbicide approved for use to control cheatgrass in the Park, and the purpose of this study is to determine the effectiveness of imazapic in cheatgrass control as well as its effects on non-target native species. In 2008, twelve permanent monitoring plots were established in six imazapic treatment sites in RMNP, each with one reference and one treatment plot. Imazapic was applied to cheatgrass infestations post-emergence in 2008 and pre-emergence in 2009 and 2010. Cheatgrass cover was reduced to approximately 3%, and there was no decrease in cover of native grasses, shrubs or forbs. This study is ongoing and will be completed in 2012.

INTRODUCTION

The Eurasian winter annual grass *Bromus tectorum* (hereafter, cheatgrass) is one of the most widespread and invasive exotic weeds of Western North America (Mack 1981). The introduction of cheatgrass to the Intermountain West of the United States is believed to have occurred in the late 1800's as a result of contaminated seed stock and intentional seeding in overgrazed grassland areas (Mack 1981). Cheatgrass aggressively invades disturbed sites (Baker 2009) and competes intensely with native plant species by maturing in early spring and rapidly establishing a root system capable of depleting soil moisture and nitrogen content (Hulbert 1955). Cheatgrass also alters natural fire regimes and can shorten fire return intervals, suppressing re-establishment of native species adapted to longer intervals and favoring further invasion by the fire-tolerant grass (Knapp 1996).

Cheatgrass infestation has increasingly become a problem in the montane and subalpine regions of Rocky Mountain National Park (RMNP), and the plant is listed as a noxious weed by both RMNP and the state of Colorado. In 2008, park management made the reduction of cheatgrass infestations in the park a priority, and the Park's exotic plant management and restoration teams have used mechanical, cultural, and chemical means for this purpose.

Included in the methods employed for the control of cheatgrass is application of the herbicide imazapic, which has been approved for limited use in RMNP for treatment of cheatgrass infestations. In 2008, permanent monitoring plots were established in sites that were infested with cheatgrass and treated with imazapic. The purpose of this study is to monitor cheatgrass infestations that have been treated with imazapic and to determine whether imazapic has a negative effect on native vegetation.This five-year study is ongoing and will conclude in 2012.

MATERIALS AND METHODS

Herbicide Application

Each year from 2008 to 2010, RMNP's exotic plant management crew treated cheatgrass infested sites with imazapic (Plateau, BASF, Research Triangle Park, USA) using backpack sprayers (23.6% a.i.). Cheatgrass was selectively spot sprayed to minimize damage to native plant species. The timing of imazapic application was changed in 2009 to comply with the revised Plateau label. In 2008 and 2009 cheatgrass plants were treated post-emergence at a maximum plant height of two inches at the time of application. Starting in 2009, all cheatgrass infestations were treated pre-emergence (soil application) to comply with the revised Plateau label. Imazapic was applied at a rate of 6 oz/ac in 2008 and 2009 and at a rate of 4 oz/ac in 2010. Application rate was decreased to avoid collateral damage to adjacent non-target plants.

Monitoring Site Selection

Monitoring sites were chosen on the basis that there was a cheatgrass infestation scheduled to be treated with imazapic and a nearby reference plot that was free of any cheatgrass and not schedule for herbicide treatment. These reference plots were judged to represent the desired final, post-treatment stage of succession for these plots. In the interest of monitoring the success of cheatgrass control in different plant communities, representative treatment and reference plot pairs were chosen from forest, shrubland and grassland sites for a total of 6 monitoring sites, each with a treatment/reference plot pair.

Vegetation Monitoring

In 2008, permanent circular nested vegetation monitoring plots (CNP) were installed at monitoring each site, each plot with an area of approximately 1810 ft^2, or 1/24 of an acre. The design of these plots consists of a circular plot with a three, 24 foot spokes at 30, 150 and 270 degrees. A 1 m^2 vegetation sampling quadrat is then placed at each of these spokes (see Fig. 1).

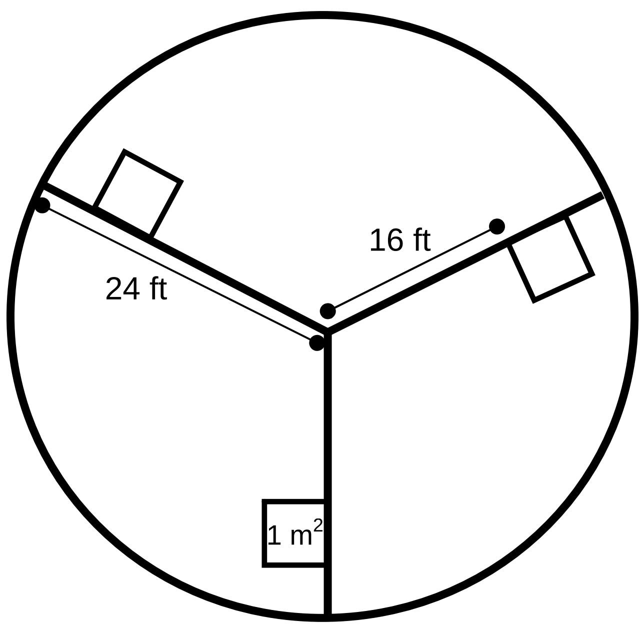

Fig. 1 Circular nested plots used to monitor vegetation at the treatment and reference sites.

To establish a permanent transect, a one foot section of rebar was driven into the ground at the center of the CNP. A 24 ft length of rope was secured to the center stake with a knot tied in the rope 16 ft from the center stake. At the 30 degree azimuth from the center stake, another rebar stake was driven into the ground at a distance of 16 ft from the center of the CNP, and this process was repeated for the 150 and 270 degree azimuths. The GPS coordinates were recorded at the center stake for each plot using a handheld Garmin Hcx GPS unit in the NAD 27 CONUS datum setting.

To survey the plant species in each plot, both percent cover and species presence were recorded. Percent cover was estimated within a 1 m^2 quadrat placed at the 30, 150 and 270 degree spokes of the CNP. For each CNP spoke, the 24 ft rope was pulled taut and wrapped once around the outer (16 ft) stake at the azimuth. The quadrat was oriented such that when facing outwards from the center stake of the CNP, the quadrat was placed with its left side against the rope and the stake positioned in the lower left corner of the quadrat (see Fig. 1). Each species present in the quadrat was recorded and an ocular estimation of percent cover for the individual species was made. Percent cover was also estimated for bare ground, litter, rock, moss and lichen and scat. Moss and lichen were only considered when growing in soil and not on rock and in 2010 scat cover was not recorded and instead included with the litter value. In general, tree, shrub and forb percent cover were estimated using canopy cover while grass and grasslike species cover were estimated using cover at ground level (basal cover). Percent cover was estimated using modified Daubenmire cover classes (Daubenmire 1959) as ranges of percent cover, with the possible percentage ranges being 0, 0-1, 1-3, 3-5, 5-10, 10-25, 25-50, 50-75 and 75-100 percent. All species within the CNP but not observed within the three quadrats were recorded. This was done by performing a time-constrained walk-through of the entire CNP, generally using 20 minutes as the observation time, and recording the species present within the perimeter of the CNP on the data sheet.

For each monitoring plot the plot name, GPS coordinates and datum, elevation, data collection date, and names of data collectors were included on the data collection sheet. At each quadrat of a CNP a picture was taken, oriented with the rope parallel to the bottom of the picture with a whiteboard in frame indicating the plot name quadrat azimuth and date of data collection.

Data Analysis

Data for each monitoring plot was entered into an Excel spreadsheet for ease of manipulation and entry into statistical analysis and graphing software. The data for each CNP were then summarized. The minimum and maximum values of the percent cover range for each species in each quadrat was averaged to produce an average percent cover value. For example, if *Chondrosum gracile* was estimated to have a percent cover of 25-50% in the 30 degree quadrat, the mean percent cover would be summarized as (25+50)/2, or 37.5% for that quadrat. After calculating the average percent cover for each species in each quadrat, the average for that species across all three quadrats was calculated.

The species in each CNP and their corresponding mean percent cover were then grouped according to growth habit and their status as either a native, non-native invasive or non-native, non-invasive species. The species richness data from the survey of the entire CNP were also grouped according to these criteria. The possible growth habit categories were tree, shrub, grass or grasslike species (including rush and sedge species), forb, or moss and lichen. Species were classified as having a particular growth habit based on their designation in the USDA PLANTS profile database and were classified as native or non-native based upon their designation as such in Weber's Colorado Flora of the Eastern Slope guide (2001). Species were classified as invasive if they were listed on RMNP's list of invasive species or the Colorado Department of Agriculture's schedule of noxious weeds. Since the focus of this study is cheatgrass management, cheatgrass presence and its percent cover were also summarized individually.

Data were analyzed using the JMP 7 statistical analysis software package (SAS Institute, Cary, NC, USA). For analysis in JMP, the data were formatted so a single row contained all of the data for one CNP. This included plot name, treatment type (treated or reference), vegetation type (forest, grassland or shrubland), and mean percent cover for each of the species categories (native shrubs, non-native forbs, etc.). The data were analyzed for each of the species categories using the multivariate analysis of variance (MANOVA) with time as a repeated measure. The between subjects factors were treatment and vegetation type, and the within subjects factor was time. For each species category, MANOVA was used to test for main effects of and interactions between treatment and vegetation type over time. If an interaction between variables was detected, this interaction was graphed using Sigma Plot 10 graphing software (Systat Software Inc., San Jose, CA, USA). If no statistically significant change in percent cover over time was detected (i.e. none of the following factors in the model were significant: time x treatment, time x vegetation type, time x treatment x vegetation type) for a species category, the percent cover for each treatment type (treated and reference) averaged across vegetation type was graphed over time for that species category. Exact F-tests or Wilk's Lamda approximate F-tests are reported as appropriate.

RESULTS

Cheatgrass

Cheatgrass cover decreased over time in response to imazapic treatment (MANOVA F-test, time x treatment interaction, P=0.02). There was a six-fold reduction in cheatgrass cover from 2008 to 2010 in sites treated with imazapic (Fig. 2).

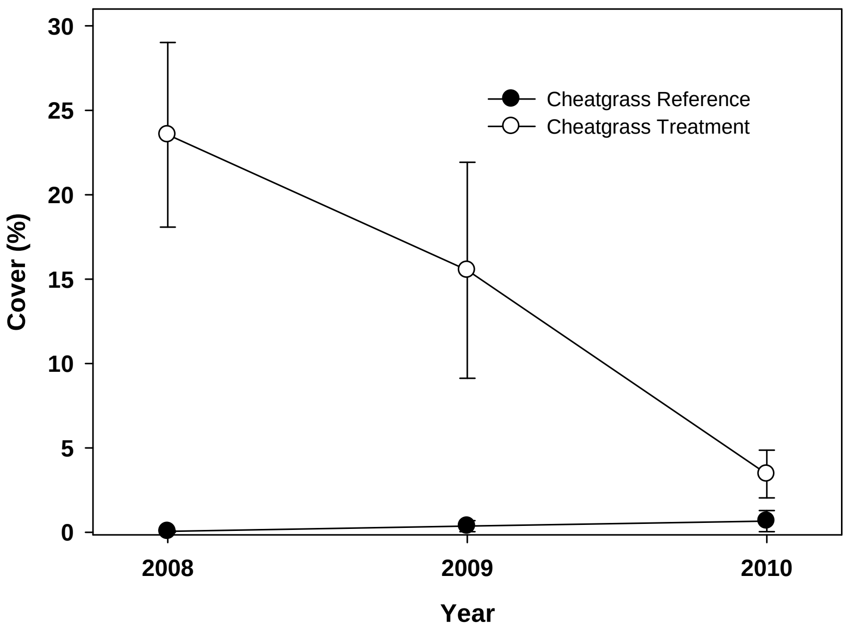

Fig. 2. Cheatgrass cover over time for plots treated with imazapic and untreated reference plots (mean ± one standard error of the mean).

Table 1. MANOVA for cheatgrass. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	5.5624	**0.0430**
Treatment	1	52.0698	**0.0004**
Veg Type x Treatment	2	6.0874	**0.0360**
Within Subjects			
Time	2	8.3698	**0.0254**
Time x Treatment	2	8.8610	**0.0227**
Time x Veg Type	4	2.0010	0.1704
Time x Veg Type x Treatment	4	2.0831	0.1647

Grass and Grasslike Species

The change in cover of all grass and grasslike species (GGS) over time depended on vegetation type (MANOVA Wilks' Lambda test, time x veg type *P*=0.01). In the grassland plots there was a 42% reduction in grass species percent cover between 2009 and 2010, whereas, there was little change over time in forest and shrubland plots (Fig. 3).

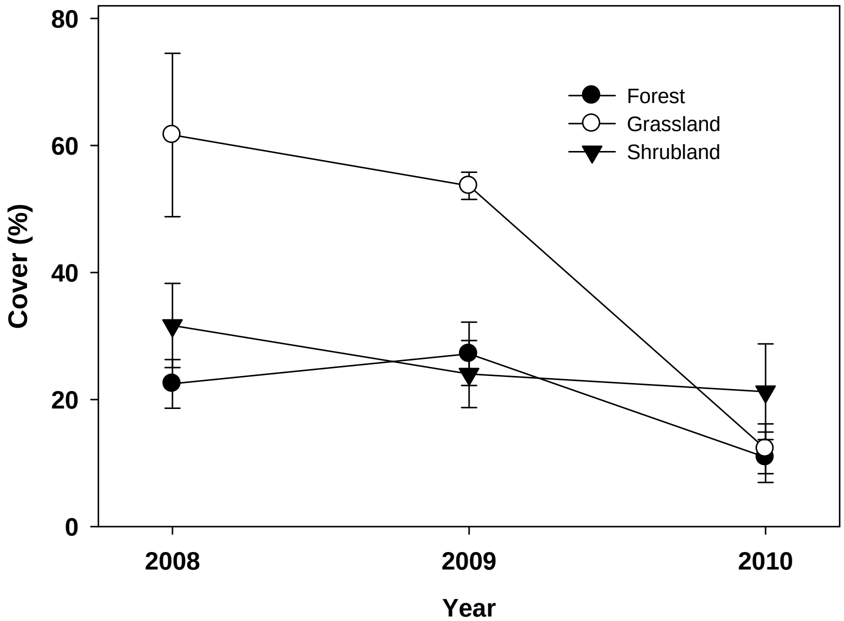

Fig. 3. Cover of all grass and grasslike species (including cheatgrass) over time was dependent on plot vegetation type (mean ± one standard error of the mean).

Table 2. MANOVA for grass and grasslike species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	1.9078	0.2284
Treatment	1	0.2534	0.6326
Veg Type x Treatment	2	0.2512	0.7856
Within Subjects			
Time	2	17.7067	**0.0054**
Time x Treatment	2	0.3185	0.7410
Time x Veg Type	4	5.3344	**0.0146**
Time x Veg Type x Treatment	4	2.1321	0.1512

Native grass and grasslike species

Change in the cover of native GGS over time depended upon treatment and vegetation type (MANOVA Wilks' Lambda test, time x vegetation type x treatment *P*=0.02). This was likely due to a 37% reduction in grassland reference plot native GGS cover from 2008 to 2009 (Fig. 4), while native GGS cover increased slightly in 2009 in some vegetation type-treatment combinations and remained essentially constant in others.

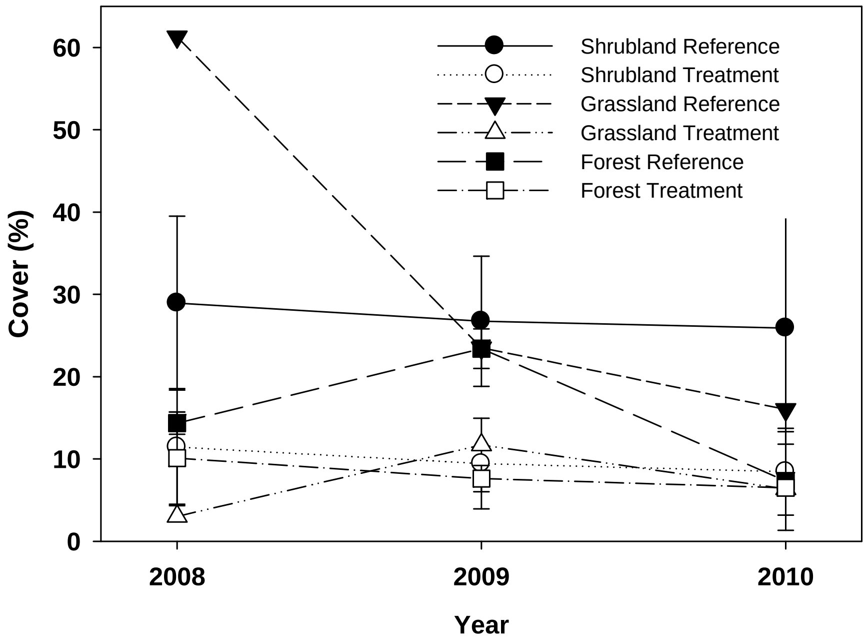

Fig. 4. Cover of native grass and grasslike species by treatment and vegetation type (mean ± one standard error of the mean).

Table 3. MANOVA for native grass and grasslike species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.5023	0.6285
Treatment	1	4.7216	0.0728
Veg Type x Treatment	2	0.4666	0.6481
Within Subjects			
Time	2	4.6222	0.0730
Time x Treatment	2	4.2662	0.0830
Time x Veg Type	4	2.5797	0.1022
Time x Veg Type x Treatment	4	4.5914	**0.0231**

Native GGS species richness in the grassland reference plot showed little change from 2008 to 2010 (Table 4).

Table 4. Species richness of native grass and grasslike species in the grassland reference plot (BLR_052).

2008	2009	2010
Hesperostipa comata [1]	*Hesperostipa comata* [1]	*Hesperostipa comata* [1]
Eleocharis spp..	*Carex ssp.*	*Carex spp.*
Koeleria macrantha	*Koeleria macrantha*	*Koeleria macrantha*
Muhlenbergia montana	*Chondrosum gracile* [1]	*Chondrosum gracile* [1]
		Muhlenbergia montana
		Poa glaucifolia

[1] Imazapic tolerant species as indicated on the 2009 Plateau label.

Non-Native, Invasive Grasses and Grasslike Species

The change in cover of non-native GGS over time depended upon treatment and vegetation type (MANOVA Wilks' Lambda test, time x veg. type x treatment P=0.0498) (Fig. 5). *Poa pratensis* was the only non-native invasive GGS species other than cheatgrass found in the grassland reference plot (Table 5). Non-native GGS cover for all other vegetation and treatment types was comparatively stable.

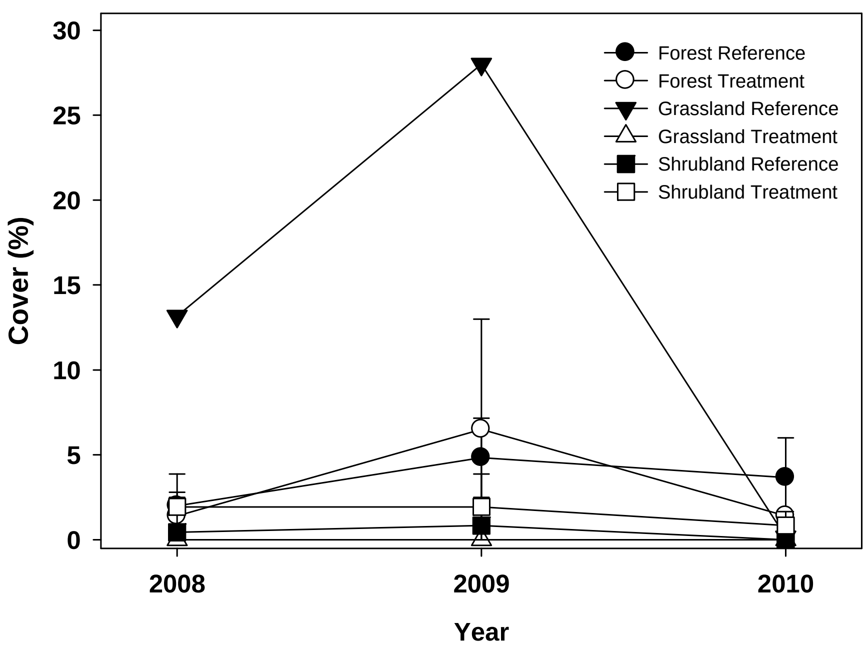

Fig. 5. Cover of non-native invasive grass and grasslike species by treatment and vegetation type (mean ± one standard error of the mean).

Table 5. Percent cover of *Poa pratensis* in the grassland reference plot.

Year	% Cover
2008	13.2
2009	28.0
2010	0.2

Table 6. MANOVA for non-native invasive grass and grasslike species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	4.7727	0.0575
Treatment	1	8.2053	**0.0286**
Veg Type x Treatment	2	7.6696	**0.0222**
Within Subjects			
Time	2	9.7427	**0.0188**
Time x Treatment	2	4.6271	0.0729
Time x Veg Type	4	4.2632	**0.0287**
Time x Veg Type x Treatment	4	3.4831	**0.0498**

Non-Native, Non-Invasive Grass and Grasslike Species
No non-native non-invasive grass or grasslike species were observed.

Forbs
No change in total forb percent cover over time was observed in plots treated with imazapic (MANOVA F-test, time x treatment *P*=0.25) (Fig. 6).

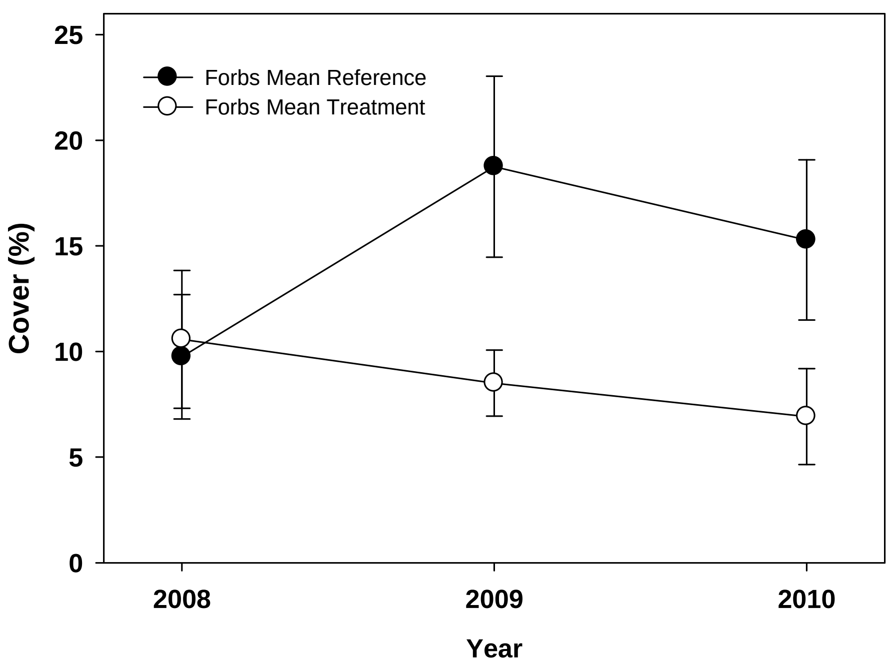

Fig. 6. Total forb cover in treatment and reference plots (mean ± one standard error of the mean).

Table 7. MANOVA for total forb species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.0629	0.9396
Treatment	1	0.9777	0.3610
Veg Type x Treatment	2	0.9722	0.4308
Within Subjects			
Time	2	1.1190	0.3966
Time x Treatment	2	1.8520	0.2501
Time x Veg Type	4	0.5606	0.6966
Time x Veg Type x Treatment	4	0.6626	0.6320

Native Forbs

There was no change in native forb cover over time in plots treated with imazapic (MANOVA F-test, time x treatment *P*=0.56) (Fig. 7).

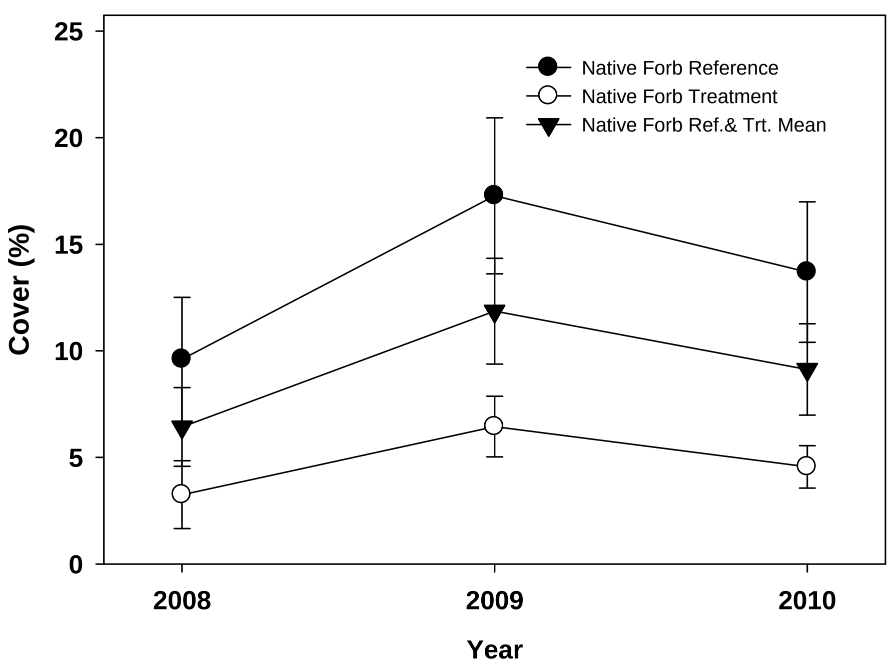

Fig. 7. Native forb cover response to imazapic treatment. The mean of all forb cover is plotted in addition to the separate reference and treatment plot data (mean ± one standard error of the mean).

Table 8. MANOVA for native forb species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Treatment	1	4.2163	0.0858
Veg Type	2	0.0822	0.9221
Veg Type x Treatment	2	1.8880	0.2312
Within Subjects			
Time	2	4.6829	0.0715
Time x Treatment	2	0.6527	0.5599
Time x Veg Type	4	0.3851	0.8146
Time x Veg Type x Treatment	4	0.1318	0.9671

Non-Native Invasive Forbs
No significant cover by non-native invasive forbs was observed the monitoring plots.

Non-Native Non-Invasive Forbs
There was no change over time in cover of non-native, non-invasive forbs in plots treated with imazapic (MANOVA F-test, time x treatment *P*=0.14) (Fig. 8). There was an apparent decrease in non-native non-invasive forb cover over time in the treatment plots, but it was not statistically significant (α=0.05) due to the extreme variability in 2008.

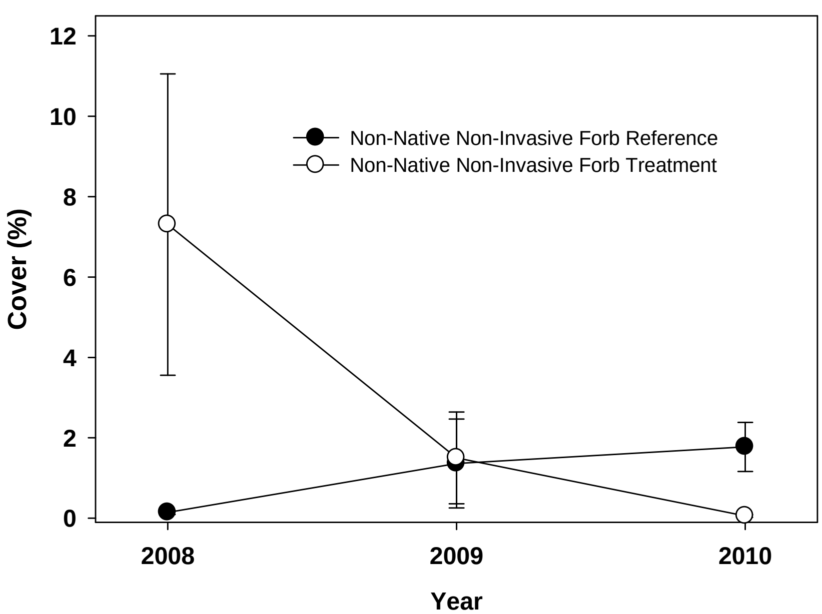

Fig. 8. Non-native non-invasive forb cover in reference plots and plots treated with imazapic (mean ± one standard error of the mean).

Table 9. MANOVA for native non-native non-invasive forb species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.3562	0.7142
Treatment	1	0.9484	0.3667
Veg Type x Treatment	2	0.8014	0.4915
Within Subjects			
Time	2	1.8740	0.2470
Time x Treatment	2	2.9790	0.1406
Time x Veg Type	4	1.9154	0.1844
Time x Veg Type x Treatment	4	0.6700	0.6275

Native Shrubs

There was no change in native shrub cover over time in plots treated with imazapic (MANOVA F-test, time x treatment *P*=0.43) (Fig. 9).

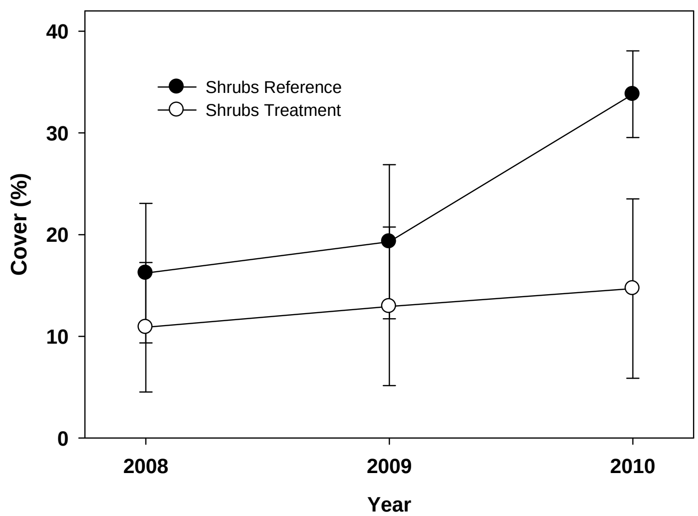

Fig. 9. Native shrub cover in reference plots and plots treated with imazapic (mean ± one standard error of the mean).

Table 10. MANOVA for native shrub species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	1.7260	0.2558
Treatment	1	0.0407	0.8469
Veg Type x Treatment	2	0.6133	0.5723
Within Subjects			
Time	2	0.5197	0.6236
Time x Treatment	2	1.0044	0.4298
Time x Veg Type	4	0.4644	0.7607
Time x Veg Type x Treatment	4	0.2263	0.9175

Native Trees
There was no change over time in native tree cover (MANOVA F-test, time x treatment P=0.19).

Table 11. MANOVA for native tree species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	4.6020	0.0615
Treatment	1	0.5985	0.4685
Veg Type x Treatment	2	0.7315	0.5197
Within Subjects			
Time	2	3.7712	0.1003
Time x Treatment	2	2.3498	0.1908
Time x Veg Type	4	2.9126	0.0776
Time x Veg Type x Treatment	4	2.0398	0.1644

Moss and Lichen
There was no change in moss and lichen cover in plots treated with imazapic (MANOVA F-test, time x treatment P=0.86) (Fig. 10).

Fig. 10. Moss and lichen cover in reference and imazapic treatment plots (mean ± one standard error of the mean).

Table 12. MANOVA for moss and lichen species. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.1480	0.8655
Treatment	1	2.5218	0.1634
Veg Type x Treatment	2	1.0483	0.4069
Within Subjects			
Time	2	0.7363	0.5245
Time x Treatment	2	0.1593	0.8569
Time x Veg Type	4	0.4890	0.7441
Time x Veg Type x Treatment	4	0.7752	0.5658

Litter

There was a change over time in litter cover in response to treatment with imazapic (MANOVA F-test, time x treatment *P*=0.04) (Fig. 11).

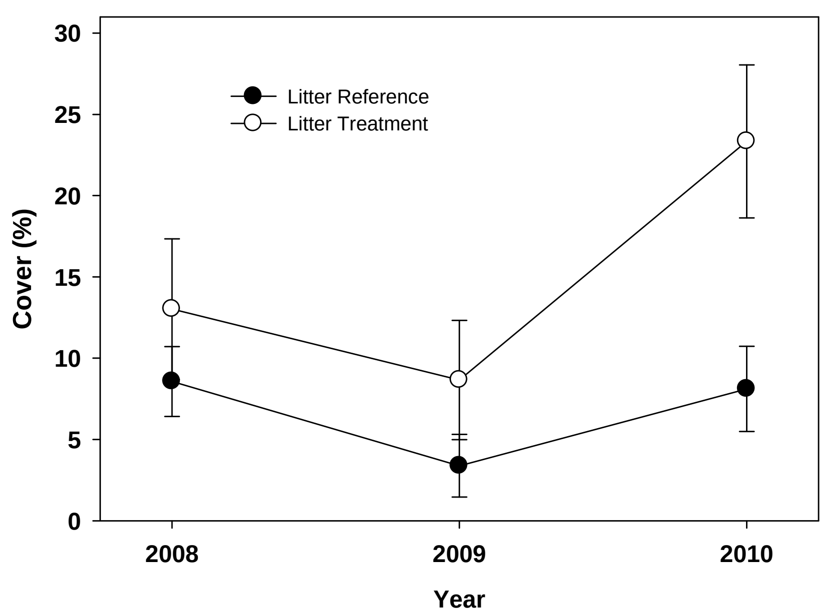

Fig. 11. Litter percent in reference plots and plots treated with imazapic (mean ± one standard error of the mean).

Table 13. MANOVA for litter cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.7469	0.5133
Treatment	1	1.8917	0.2182
Veg Type x Treatment	2	0.1744	0.8441
Within Subjects			
Time	2	18.9723	**0.0046**
Time x Treatment	2	6.8734	**0.0367**
Time x Veg Type	4	1.0750	0.4186
Time x Veg Type x Treatment	4	1.5384	0.2641

Bare Ground

There was no change over time in bare ground cover in response to imazapic treatment (MANOVA F-test, time x treatment, *P*=0.94) (Fig. 12).

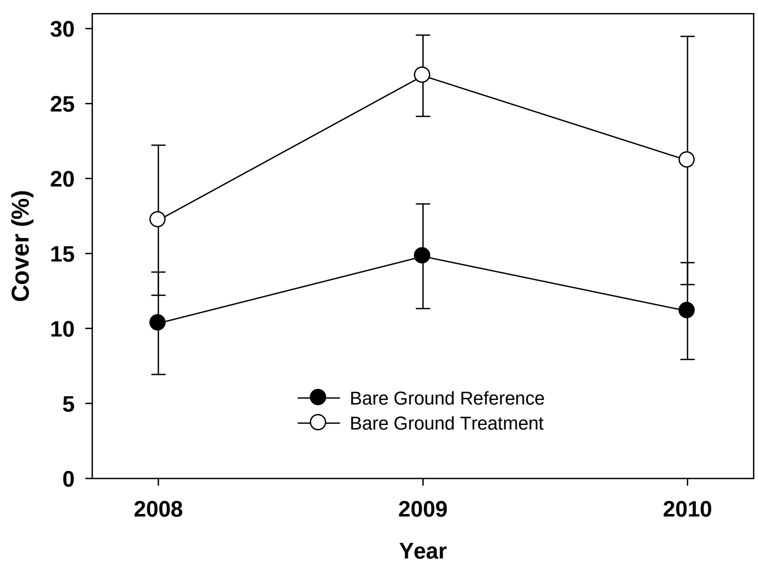

Fig. 12. Bare ground cover in treatment and reference plots (mean ± one standard error of the mean).

Table 14. MANOVA for bare ground. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.3464	0.7205
Treatment	1	4.2890	0.0838
Veg Type x Treatment	2	0.9732	0.4305
Within Subjects			
Time	2	0.6764	0.5496
Time x Treatment	2	0.0651	0.9377
Time x Veg Type	4	2.3895	0.1203
Time x Veg Type x Treatment	4	0.7055	0.6061

Rock
There was no change in rock cover over time in response to imazapic treatment (MANOVA F-test, time x treatment P=0.72)

Table 15. MANOVA for rock cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.3778	0.7006
Treatment	1	0.0847	0.7808
Veg Type x Treatment	2	0.1290	0.8813
Within Subjects			
Time	2	0.8055	0.4975
Time x Treatment	2	0.3523	0.7192
Time x Veg Type	4	0.6181	0.6597
Time x Veg Type x Treatment	4	0.2816	0.8833

Scat
There was no change in scat cover over time in response to imazapic treatment (MANOVA F-test, time x treatment P=0.97)

Table 16. MANOVA for scat cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	2.1572	0.1968
Treatment	1	0.0733	0.7956
Veg Type x Treatment	2	0.7842	0.4982
Within Subjects			
Time	2	9.8458	0.0882
Time x Treatment	2	0.0305	0.9701
Time x Veg Type	4	0.7778	0.5643
Time x Veg Type x Treatment	4	0.3078	0.8663

All Species and All Native Species
Total cover of all species changed over time independent of treatment type (MANOVA F-test, time P=0.03), and there was no change in cover of native species taken together (MANOVA F-test, time x treatment P=0.31) (Fig. 13).

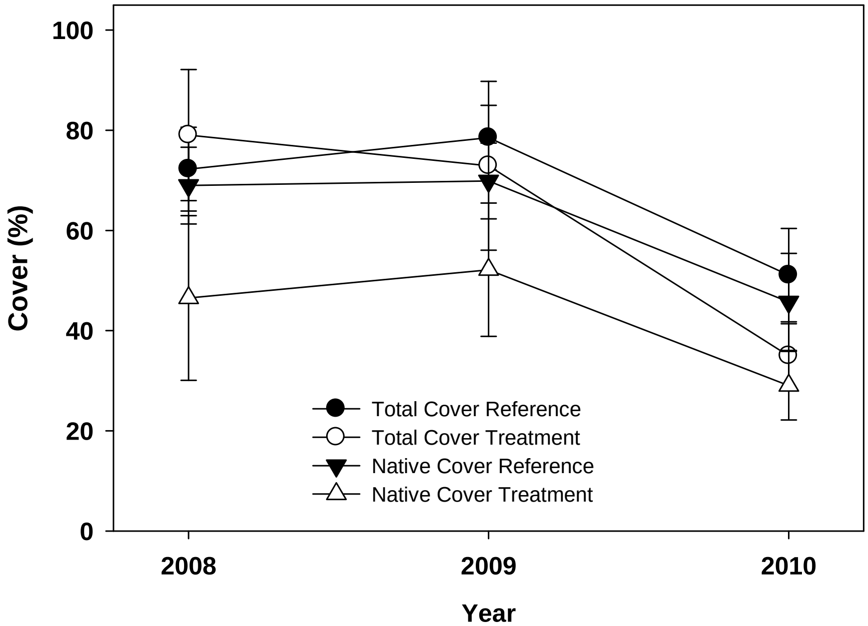

Fig. 13. Total cover of all species and all native species.
(mean ± one standard error of the mean)

Table 17. MANOVA for total species cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.3423	0.7231
Treatment	1	0.1514	0.7106
Veg Type x Treatment	2	0.1859	0.8350
Within Subjects			
Time	2	8.2229	**0.0262**
Time x Treatment	2	0.5359	0.6154
Time x Veg Type	4	1.5287	0.2666
Time x Veg Type x Treatment	4	0.7555	0.5769

Table 18. MANOVA for total native species cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	1.4964	0.2970
Treatment	1	2.6347	0.1557
Veg Type x Treatment	2	0.4865	0.6371
Within Subjects			
Time	2	3.6291	0.1063
Time x Treatment	2	1.4700	0.3147
Time x Veg Type	4	1.6308	0.2415
Time x Veg Type x Treatment	4	1.8320	0.1994

All Non-Native Invasive Species and All Non-Native Non-Invasive Species
Total cover of all non-native invasive species changed over time independent of treatment type (MANOVA F-test, time P=0.01). Cover of non native non-invasive species did not change over time (MANOVA F-test, time x treatment P=0.11) (Fig. 14).

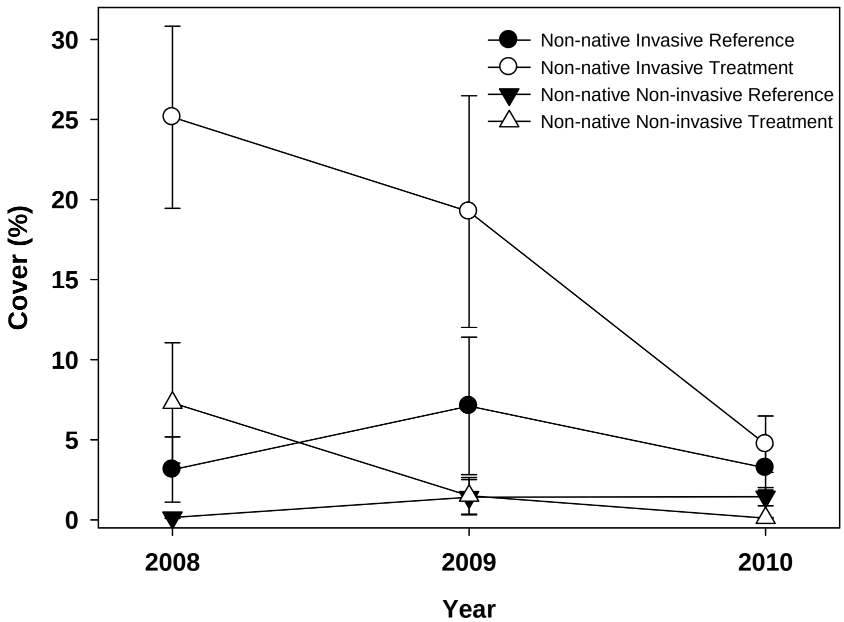

Fig. 14. Cover for all non-native invasive species and all non-native non-invasive species in reference plots and plots treated with imazapic (mean ± one standard error of the mean).

Table 19. MANOVA for total non-native invasive species cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	4.4659	0.0649
Treatment	1	10.6813	**0.0171**
Veg Type x Treatment	2	0.2095	0.8167
Within Subjects			
Time	2	11.2030	**0.0142**
Time x Treatment	2	4.7095	0.0708
Time x Veg Type	4	2.9514	0.0752
Time x Veg Type x Treatment	4	0.2876	0.8795

Table 20. MANOVA for total non-native non-invasive species cover. Statistically significant p-values in bold.

Source of Variation	df	*F-statistic*	*P*-value
Between Subjects			
Veg Type	2	0.3080	0.7459
Treatment	1	1.1543	0.3240
Veg Type x Treatment	2	0.8622	0.4687
Within Subjects			
Time	2	1.4861	0.3151
Time x Treatment	2	3.4962	0.1122
Time x Veg Type	4	1.4961	0.2752
Time x Veg Type x Treatment	4	0.8387	0.5311

DISCUSSION

Cheatgrass

Results of this study through 2010 suggest that cheatgrass cover is being reduced in plots treated with imazapic. From 2008 to 2010 there has been a 20% reduction in the average percent cover of cheatgrass in treatment plots. Although these results are encouraging, no untreated control plots were included in the design of this study, so the reduction in cheatgrass cover may be a result of factors other than imazapic treatment alone.

Grass and Grasslike Species (GGS)

The decrease in total GGS percent cover observed in grassland plots was likely the result of several trends: (1) the reduction of cheatgrass cover in the treatment plot from 46% in 2008 to 2% in 2010, (2) the decrease in native GGS cover in the reference plot from 61% in 2008 to 16% in 2010 and (3) the decrease in *Poa pratensis* cover in the reference plot from 28% in 2009 to approximately 0.2% in 2010.

The decrease in native GGS in the reference plot from 2008 to 2010 may be the result of several factors. Native GGS species richness does not appear to be diminished between 2008 and 2010 (Table 1), so it is unlikely that a simple loss of species is the cause of reduced native GGS cover. It is highly unlikely that the grassland reference plot was inadvertently treated with imazapic as the reference plot is approximately 100 m from the treatment area. Also, the exotic plant management crew abides by a strict no-spray policy if winds exceed speeds deemed likely to spread herbicide to non-target areas. Furthermore, most of the species present in the reference plot data are not listed as imazapic tolerant, and we would expect that a plot treated with imazapic would have few to no imazapic intolerant species present. Herbivory is a possible factor in the reduced cover of native GGS in the reference plot, as this plot is located in an area with elk or deer droppings amongst the vegetation (personal observation). Climate variation may also have had an effect on grass cover from year to year. It is possible that the ocular percent cover estimations made year to year varied with the individuals making the estimation. Different individuals have estimated cover in each of the three years of the study. Data from the 2011 season should provide more insight into whether variation among individuals making measurements is influencing this trend.

The decrease in non-native, invasive GGS (excluding cheatgrass) in the grassland reference plot is likely due to the decrease in *Poa pratensis* cover from a high of 28% in 2009 to only 0.2% in 2010. *Poa pratensis* was the only other invasive grass found in the reference plot. Past data records from 2008 and 2009 list *Poa pratensis* with a note indicating that the grass species observed may not actually be *Poa pratensis*. It is possible that in 2010 we classified the same grass as an entirely different species, which led to the decrease in cover that year. Again, there were different crews estimating cover for this plot each year of this study, so data from 2011 may provide insight into this trend.

All Species and All Native Species

The change in the total percent cover by all species in all vegetation and treatment types may be the result of decreases in the percent cover of all species in grassland and forest plots as well as decreases in cheatgrass cover. The decrease in cover of all species in the grassland plots from 2009 to 2010 (95% to 33%, respectively) is likely due to the decrease in native GGS in the reference plot discussed above. Decreased cover in forested plots 2009 to 2010 (72% to 23%, respectively) is due to the lack of large tree percent cover data for 2010. Percent cover for large tree canopy cover was not recorded in 2010 due to a misunderstanding of the data collection protocol, and in the future large tree canopy cover, which tends to be significant in forest plots, will be recorded as it was in past years.

The percent cover of all native species did not show any significant changes across vegetation and treatment types over time, suggesting that native species may not be experiencing non-target effects of herbicide application thus far.

Non-Native, Invasive Species and Non-Native, Non-Invasive species

The drop in percent cover of non-native invasive species is due predominantly to the decreased cheatgrass percent cover, suggesting that imazapic is successfully reducing non-native invasive species in treated plots. As mentioned above, without an untreated control for imazapic applications, the change cannot be definitively attributed to the herbicide. Non-native, non-invasive species have not experienced a significant change in percent cover.

Forbs and Shrubs

None of the categories of forbs or shrubs experienced a significant change in percent cover, though native forb cover tended to be greater in reference plots. Although these results suggest that there have been no negative impacts of imazapic application on native forbs thus far, this trend of decreased native forb cover should be closely monitored in the future. A study to monitor the effects of pre-emergent imazapic treatment of cheatgrass in Colorado's Dry Creek Basin found that an imazapic application rate of 175g/ha (~2.5oz/ac) significantly reduced biomass and cover of native forb species (Baker 2009). This application rate is significantly lower than those used in this study (6 and 4 oz/ac). In Baker's study, no attempt was made to avoid treating native species with imazapic, and one question raised by Baker was whether selective imazapic application would lessen this negative effect on forbs, which is what we have observed in RMNP where treating natives is avoided.

Litter, Scat, Rock, Bare Ground

While there was a change observed in the percent cover of litter from 2009 to 2010 in the treatment plots, this may be the result of the scat data being consolidated with the litter data in 2010.

There was no change observed in the scat or rock percent cover. There was also no change in the percent cover of bare ground in plots treated with imazapic, suggesting that there hasn't been a denuding effect from herbicide application.

CONCLUSION

The data collected thus far appear to indicate that imazapic application has been effective in controlling cheatgrass while having limited negative impact on native grasses, forbs and shrubs. However, the lack of an untreated control for imazapic limits the inferences that can be drawn.

Further study could address the question of what effect selectively spraying cheatgrass and avoiding natives has on native survival compared to the effectiveness of cheatgrass control. Large shrubs could potentially provide refuge for cheatgrass plants and seeds and act as a source for reinfestation after imazapic treatment has ceased. Also, having the same individuals collect data in consecutive years may help identify the effect of more conservative or liberal ocular percent cover estimation by different monitoring crews. Finally, future studies should include true control plots that are identical to the treatment plots but are not treated with herbicide. Without such controls, we cannot be absolutely sure that changes in cheatgrass cover are due to imazapic treatment alone or other factors such as weather, herbivory or natural fluctuations in species composition.

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IMPACT OF FIRE ON CHEATGRASS INFESTATIONS IN MONTANE FORESTS OF ROCKY MOUNTAIN NATIONAL PARK

INTRODUCTION

The Eurasian winter annual grass *Bromus tectorum* (hereafter, cheatgrass) is one of the most widespread and invasive exotic weeds of Western North America (Mack 1981). The introduction of cheatgrass to the intermountain West region of the United States is believed to have occurred in the late 1800's as a result of contaminated seed stock and intentional seeding in overgrazed grassland areas (Mack 1981). Cheatgrass aggressively invades disturbed sites (Baker 2009) and competes intensely with native plant species by maturing in early spring and rapidly establishing a deep root system capable of depleting soil moisture and nitrogen content (Hulbert 1955). Cheatgrass also alters natural fire regimes and can shorten fire return intervals, suppressing re-establishment of native species adapted to longer intervals without fire and favoring further invasion by the fire-tolerant grass (Knapp 1996).

Cheatgrass infestation has increasingly become a problem in the montane and subalpine regions of Rocky Mountain National Park (RMNP), and is listed as a noxious weed by both RMNP and the state of Colorado. In 2008, Park management made the reduction of cheatgrass infestations a priority, and the park's exotic plant management and restoration teams have used mechanical, cultural and chemical means for this purpose.

Application of the herbicide imazapic is one method employed for the control of cheatgrass. Imazapic has been approved for limited use in RMNP for treatment of cheatgrass infestations, along with prescribed burns. In 2009, permanent plots were established to monitor the effect of spring and fall prescribed fires in combination with pre-burn imazapic treatment on heavily infested cheatgrass sites and nearby intact native plant communities, including imperiled *Purshia tridentata* shrubland plant alliances (*Purshia tridentata, Artemisia frigida, Hesperostipa comata, Muhlenbergia montana*). Only pre-burn baseline data are reported here. This five-year study is ongoing and will conclude in 2013.

MATERIALS AND METHODS

Herbicide Application

In September 2010, Rocky Mountain National Park's exotic plant management crew treated cheatgrass pre-emergence on the South Lateral Moraine with imazapic (Plateau, BASF, Research Triangle Park, USA) using backpack sprayers (23.6% a.i., 4 oz/ac). During imazapic application, the exotics crew attempted to selectively spray bare soil around and under cheatgrass infestations while avoiding spraying native plant species.

Prescribed Burn

A prescribed burn along the south aspect of the SLM was planned for 2009 and 2010, but was not performed due to prescription conditions not being met. The burn will be contained along a ridge on the eastern portion of the moraine to allow for an unburned control area (Fig. 1).

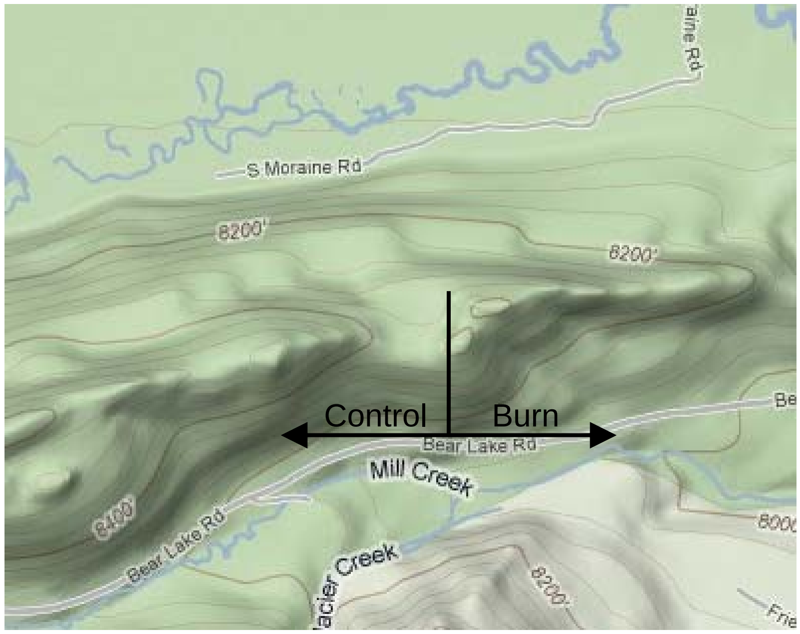

Fig. 1. Map of planned burn and control areas for the South Lateral Moraine prescribed fire. Monitoring plots have been established in both areas.

Vegetation Monitoring

In 2009, 18 circular nested plots (CNPs) (1810 ft^2 or 1/24 ac) were installed along the south aspect of the SLM adjacent to Moraine Park. The control area and burn area each have nine permanent CNPs that were infested with cheatgrass when established in 2009. As described above, the plots were treated with imazapic before cheatgrass emergence in September 2010.

CNPs consist of a circle with a diameter of 48 ft with three 24 ft spokes at 30, 150 and 270 degrees. A 1 m^2 vegetation sampling quadrat is then placed at 16 ft from the center of the circle on each of these spokes (Fig 2).

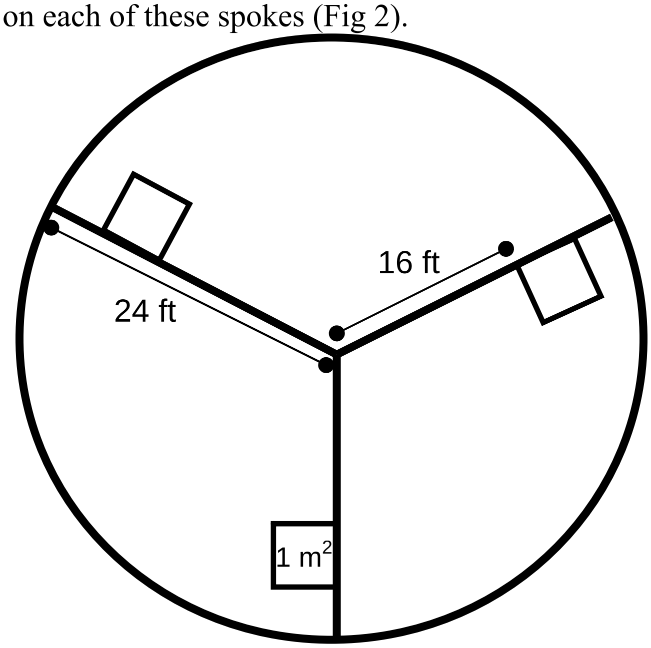

Fig. 2. Circular nested plots used to monitor vegetation at the treatment and control sites.

To establish a permanent transect, a 1 ft section of rebar was driven into the ground at the center of the CNP. A 24 ft length of rope was secured to the center stake with a knot tied in the rope 16 ft from the center stake. At the 30 degree azimuth from the center stake, another rebar stake was driven into the ground at a distance of 16 ft from the center of the CNP, and this process was repeated for the 150 and 270 degree azimuths. The GPS coordinates were recorded at the center stake for each plot using a handheld Garmin Hcx GPS unit in the NAD 83 datum setting (Table 1).

To survey the plant species in each plot, both percent cover and species presence were recorded. Percent cover was estimated within a 1 m^2 quadrat placed at the 30, 150 and 270 degree spokes of the CNP. For each CNP spoke, the 24 ft rope was pulled taut and wrapped once around the outer (16 ft) stake at the azimuth. The quadrat was oriented such that when facing outwards from the center stake of the CNP, the quadrat was placed with its left side against the rope and the stake positioned in the lower left corner of the quadrat (Fig. 1). Each species present in the quadrat was recorded and an ocular estimation of percent cover for the individual species was made. Percent cover was also estimated for bare ground, litter, rock, moss and lichen, and scat. Percent cover of moss and lichen were only estimated when growing in soil and not on rock. In 2010, scat cover was not recorded and was instead included with the litter value. In general, tree, shrub, and forb percent cover were estimated using canopy cover while grass and grasslike species cover were estimated using cover at ground level (basal cover). Percent cover was estimated using modified Daubenmire cover classes (Daubenmire 1959) as ranges of percent cover, with the possible percentage ranges being 0, 0-1, 1-3, 3-5, 5-10, 10-25, 25-50, 50-75 and 75-100 percent. All species that were present within the CNP, but not observed within the three quadrats, were recorded. This was done by performing a time-constrained walk-through of the entire CNP, generally using 20 minutes as the observation time, and recording the species present within the perimeter of the CNP on the data sheet.

For each monitoring plot, the plot name, GPS coordinates, datum, elevation, data collection date, and names of data collectors were included on the data collection sheet. A picture was taken at each quadrat of each CNP, oriented with the rope parallel to the bottom of the picture with a whiteboard in frame indicating the plot name, quadrat azimuth, and date of data collection.

Table 1: South lateral moraine plot locations; BSLME: Burn plots; CSLME: Control Plots

South Lateral Moraine		Datum: NAD83
Transect	**UTME**	**UTMN**
BSLME_001	450465	4466552
BSLME_002	450450	4466528
BSLME_003	450419	4466533
BSLME_004	450387	4466522
BSLME_005	450332	4466536
BSLME_006	450300	4466537
BSLME_007	450259	4466515
BSLME_008	450233	4466545
BSLME_009	450176	4466525
CSLME_010	449800	4466354

CSLME_011	449753	4466370
CSLME_012	449710	4466363
CSLME_013	449683	4466337
CSLME_014	449584	4466289
CSLME_015	449455	4466268
CSLME_016	449419	4466237
CSLME_017	449420	4466164
CSLME_018	449386	4466141

Data Analysis

Data for each monitoring plot were entered into an Excel spreadsheet for ease of manipulation and entry into statistical analysis and graphing software, and the data for each CNP were then summarized. The minimum and maximum values of the percent cover range for each species in each quadrat were averaged to produce an average percent cover value. For example if *Chondrosum gracile* was estimated to have a percent cover of 25-50% in the 30 degree quadrat, the mean percent cover would be summarized as (25+50)/2, or 37.5% for that quadrat. After calculating the average percent cover for each species in each quadrat, the average for that species across all three quadrats was calculated.

The species in each CNP and their corresponding mean percent cover were then grouped according to growth habit and their status as either a native, non-native invasive or non-native non-invasive species. The species richness data from the survey of the entire CNP were also grouped according to these criteria. The possible growth habits were tree, shrub, grass or grasslike species (including rush and sedge species), forb, or moss and lichen and species were classified as having a particular growth habit based on their designation in the USDA PLANTS profile database. Species were classified as native or non-native based upon their designation as such in Weber's Colorado Flora of the Eastern Slope guide (2001). Species were classified as invasive if they were listed on Rocky Mountain National Park's list of invasive species or the Colorado Department of Agriculture's schedule of noxious weeds. Since the focus of this study is cheatgrass management, cheatgrass and its percent cover were also summarized individually.

Data were analyzed using the JMP 7 statistical analysis software package (SAS Institute, Cary, NC, USA). For analysis in JMP, the data were formatted so a single row contained all of the data for one CNP. This included plot name, treatment type (treated or reference), vegetation type (forest, grassland or shrubland), and mean percent cover for each of the species categories (native shrubs, non-native forbs, etc.). The data were analyzed for each of the species categories using the analysis of variance (ANOVA) model. For each species category, ANOVA was used to determine if there were differences in species cover over time between plots assigned to control and burn treatments before the treatments were applied. If an interaction between variables was found, this interaction was graphed using Sigma Plot 10 graphing software (Systat Software Inc., San Jose, CA, USA).

RESULTS

Cheatgrass

Cover of cheatgrass in 2010 was greater in the plots assigned to the control treatment than to the burn treatment (ANOVA F-test, P=0.04). There was no difference in cheatgrass cover in the previous year (Fig. 3).

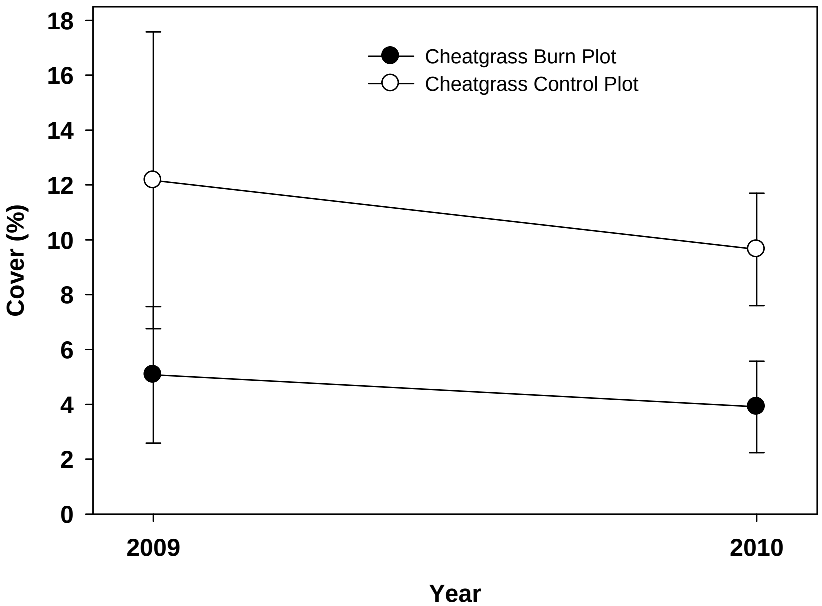

Fig. 3. Change in cheatgrass cover over time (mean ± one standard error).

Invasives (Non-native)

Cover of non-native invasive species in 2010 was greater in plots assigned to the control treatment than to the burn treatment (ANOVA F-test, P=0.04). There was no difference in non-native invasive species cover detected in the previous year (Fig. 4).

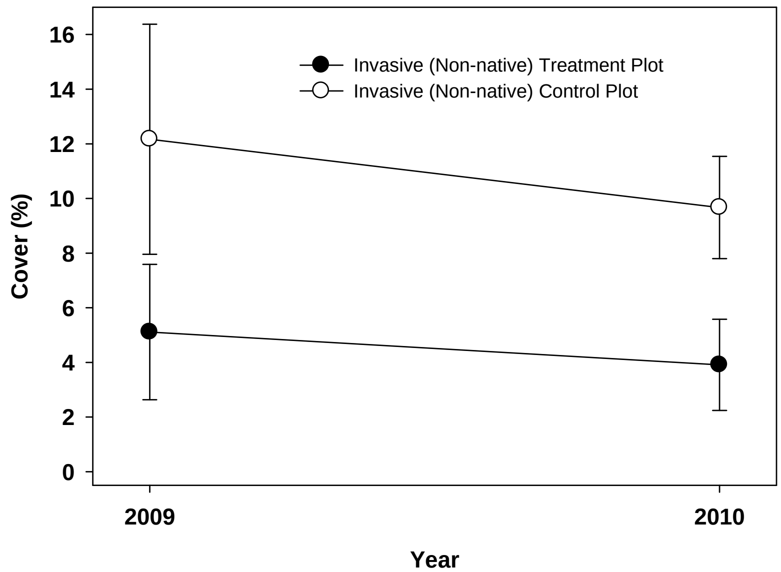

Fig.4. Change in non-native invasive species over time (mean ± one standard error).

Forbs

Cover of forbs in 2010 was greater in plots assigned to the control treatment than to the burn treatment (ANOVA F-test, P=0.006). There was no difference in forb cover the previous year (Fig. 5).

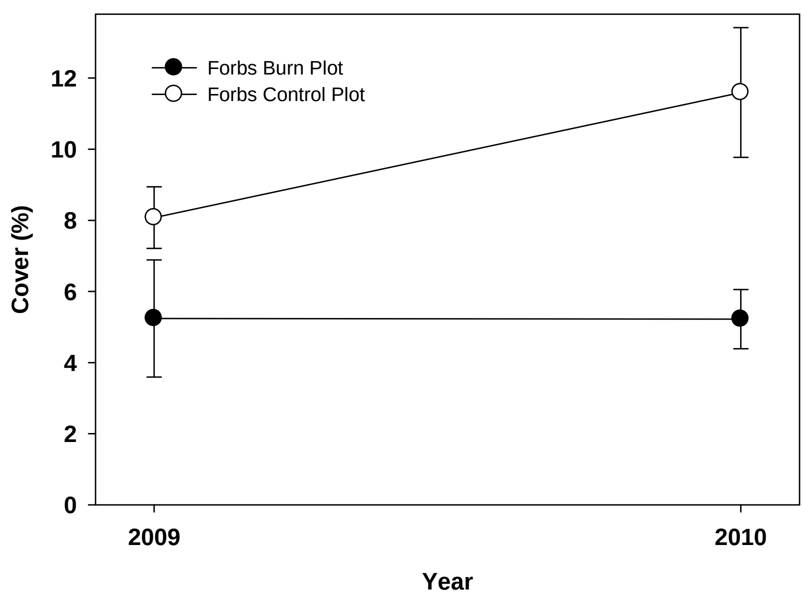

Fig. 5. Change in forb cover over time (mean ± one standard error).

Native Forbs
Cover of native forbs in 2010 was greater in plots assigned to the control treatment than to the burn treatment (ANOVA F-test, P=0.01). There was no difference in native forb cover in the previous year (Fig. 6).

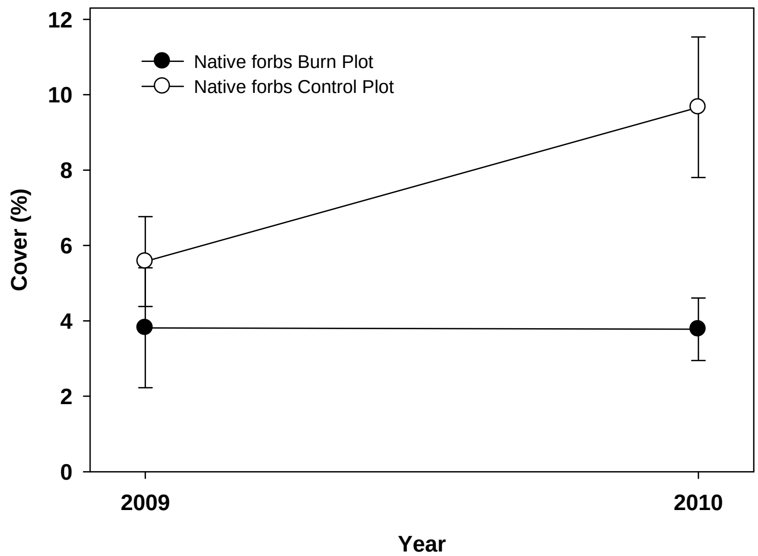

Fig. 6. Change in native forb cover over time (mean ± one standard error).

Bare soil
Cover of bare soil in 2009 was greater in control plots than in burn plots (ANOVA F-test, P=0.0009). There was no difference in bare soil cover in 2010 (Fig. 7).

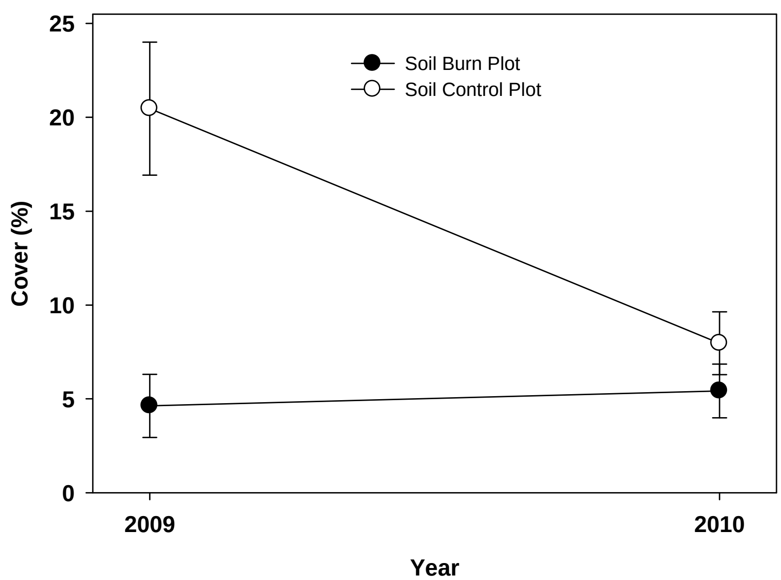

Fig. 7. Change in bare soil cover over time (mean ± one standard error).

Cover of all other species categories was determined to be the same between both burn and control plots for 2009 and 2010.

DISCUSSION

The purpose of this study is to monitor the effect of spring and fall prescribed fires on heavily infested cheatgrass sites and intact native plant communities that are in close proximity to areas heavily infested with cheatgrass when imazapic has been used to control cheatgrass prior to burning. As prescribed burns have not yet been conducted on the SLM due to unsuitable environmental conditions, 2 yrs of baseline data have been collected. Cover of native forbs as well as all forbs combined was relatively greater in the pre-treatment burn plots than the control plots in the second year, but not the first year. Conversely, cover of bare ground was relatively greater in the control plots than the pre-treatment burn plots in the first year, but not the second year.

Knowing prior to treatment that there were differences in the cover of particular species categories as well as the rate at which cover values have changed will be useful in avoiding misinterpretation of the post-burn data. These differences in vegetation cover may be due to variance in the slope, aspect, soil type and nutrient content, and disturbance history between the burn and control areas of this study.

The design of this study does not include plots that include all combinations of treatments and controls, which will limit inferences that can be made about the effects of the prescribed fire and herbicide applications. This may be unavoidable as cheatgrass control is a priority at RMNP and fire disturbed plots are at increased risk of invasion from adjacent cheatgrass infestations. Another characteristic of this study inherent to the management goals of this prescribed fire is the segregation of burn and control monitoring plots. This segregated arrangement of samples leads to pseudoreplication (Hurlbert 1984). Hurlbert (1984) suggests that sampling of experimental units that are not truly independent decreases the inferential power of a study and results are best interpreted by graphical analysis of sample means and standard deviations of each experimental unit. The experimental units in the case of this study would be the burn unit and the control unit.

Suggestions for future monitoring of these plots include collection of soil data as well as the establishment of plots that include all combinations of burn and herbicide treatments, if suitable sites exist. It would also be beneficial to conduct one or two additional controlled burns and establish paired burned and unburned control plots for each. These additional control burns will represent true replications of the burn treatment, correcting the problem with pseudoreplication and allowing the use of parametric statistics to analyze the effect of burning.

CONCLUSION

The data collected thus far give the study a strong baseline collection. Hopefully prescription conditions can be met in the spring or fall of 2011 to allow for post-treatment data collection.

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FAN LAKE WETLAND RESTORATION EVALUATION 2010

INTRODUCTION

The 1982 breach of the Lawn Lake Dam in Rocky Mountain National Park (RMNP) sent 831,000 m^3 of water flowing down the channel of the Roaring River. This torrent of water eroded and transported large quantities of sediment from the Roaring River channel and deposited it as an alluvial fan near the confluence of the Roaring and Fall Rivers in Endo Valley. Flood impacts continued downstream to the town of Estes Park, causing three fatalities and $36 million in damages. The alluvial fan filled a significant portion of the Fall River channel and abutted a portion of a lateral moraine on the other side of the channel. This blocked the flow of the Fall River and formed a 17 acre impoundment, hereafter referred to as “Fan Lake.” Fearing catastrophic failure of the impoundment and further damage to the downstream community of Estes Park, RMNP staff created a breach at the head of the lake in 1995, partially draining Fan Lake.

Creation of the alluvial fan and Fan Lake had a variety of direct and indirect adverse effects on the native riparian and wetland communities of Endo Valley and Horseshoe Park. Most notably, a large area of riparian shrub community (willow carr) was lost when it was converted to bare sediment, open water, or marsh-type wetlands. The debris fan and flooded areas impacted several local beaver communities due to the loss of this willow carr, eliminating their primary food source and dam building material (willows). The willow carr was also breeding habitat for a number of Colorado bird species of conservation interest, which are also RMNP’s high priority species. The broad-tailed hummingbird, red-naped sapsucker, Wilson’s warbler, Macgillivray’s warbler, and the Cordilleran flycatcher lost breeding or foraging habitat. Other neo-tropical birds that were impacted include the Lincoln sparrow, yellow warbler, song sparrow, dusky flycatcher and fox sparrow. A rare species of shrew as well as the boreal toad were also negatively impacted. All of these impacts lead RMNP to assess the area for restoration possibilities. In 2005 Colorado State University researchers, David Cooper and Ed Gage, began assessment of the area, and after a year, devised possible restoration plan in their report “Fan Lake and Fall River Restoration: Site Characterization, Design Elements, and Recommendations” (Cooper and Gage, 2006).

During the fall of 2006 the restoration of Fan Lake began. The first task was to drain Fan Lake which was done using two techniques. First, water flow was cut off from the new Roaring River tributary that fed Fan Lake. This was done by the construction of an earthen dam at the tributaries confluence with the Roaring River. This dam rerouted water back into the historic track of the Roaring River draining the tributary and thus helping to drain Fan Lake. In addition to the earthen dam, the Fall River channel was dredged just above the confluence with the Roaring River. This technique allowed a greater volume of water to move downstream aiding in the draining action of Fan Lake. Both techniques simultaneously lowered the water level, creating new wetland and riparian habitat. In July 2007 a 31 acre elk exclosure was erected around the wetland and restoration site.

During August of 2007, Wildland Restoration Volunteers (WRV), a volunteer organization based in Boulder, CO help plant the restoration site. A total of 18,529 plants were planted over two days. Table 1 shows species and numbers planted. All plants were grown in a greenhouse setting, except for willows. Willows cuttings were taken from adjacent communities and then rooted in the RMNP greenhouse.

Table 1. Number of each species planted in the Fan Lake wetland restoration site.

Species	**Number of Plants**
Carex utriculata	5,614
Carex aquatilis	10,615
Calamagrostis canadensis	400
Juncus saximontanus	1000
Salix sp.	900
TOTAL	**18,529**

In order to achieve the restoration goals successfully, a monitoring program has been established to evaluate the success of this restoration effort and identify the need for potential follow up treatments. Essentially, the program will monitor the success of the restoration efforts, as well as record the progress of natural regeneration, new species colonization, and exotic invasions. This five-year study in ongoing and will conclude in 2011.

METHODS

The area of the wetland site was approximately 3.8 ac. Four belt transects were permanently installed in the wetland using rebar. Each transect was 20 m^2 in 2 x 10 m arrangements. Three transects (T1, T2 and T3) were placed within the wetland in locations that were representative of the restoration site. The fourth transect (T4) was intended to be the control or reference transect. This transect is to be used as a model for what the other transects should look in the future. GPS locations at the southeast corner point of each transect were recorded in the NAD83 datum and are listed below in Table 2.

Table 2. UTM Coordinates for monitoring transects in Fan Lake restoration site.

Transect	**UTMN**	**UTME**
T1	445820	4473354
T2	445776	4473297
T3	445826	4473323
T4 Control	445855	4473310

Transects were sampled in 2007 (no date recorded), September 2008, early August 2009, and early August 2010. In each transect the presence and names of all species were recorded as either a Yes or No. Additionally, the five species that were deliberately planted in the wetland by Rocky Mountain National Park were counted. Therefore, the initial inventory quantifies *Carex utriculata*, *Carex aquatilis, Calamagrostis canadensis*, *Salix spp*., and *Juncus saximontanus*. In addition to monitoring natives, it was also a priority to monitor the exotics that appeared in the wetland. Because of the high amount of disturbance within the wetland, the ecosystem remains very vulnerable to exotic invasions; therefore any exotic species found within the transects were counted so that their presence may be closely observed. This method will allow both the observation of natural succession, as well as monitor the success of the planted species.

RESULTS

The four transects at Fan Lake decrease in wetness from Transect 1 to Transect 4. By estimating Transect 1's location with GPS coordinates and past years' pictures, it seems the plot is within a sandy location with a large amount of water flowing through it, especially in 2010. Transect 1 is located in an area that is lower and wetter than the other transects. Transect 2 lies adjacent to the stream, but in an area that is less wet than T1. Transect 3 is in an area that is higher and drier than T1, T2 and T4 and is located on what looks like a sandbar. Transect 4, the reference plot, is located in an area near T3, which is not quite as dry, but not as wet as T1 and T2.

Transect 1

Table 3 shows species densities surveyed in T1 along with species richness. All planted species increased in density except for *Juncus saximontanus*, which decreased by 1.5 plants/m^2 from 2007 to 2009 (Fig. 1). *Carex spp.* dominated the community in 2007 and 2009 with *Salix spp.* and *Calamagrostis canadensis* appearing in 2009. The total species richness in T1 increased from three in 2007 to 17 in 2009. The invasive exotic grass *Phleum pratense* was also established in the plot in 2009, but it was the only invasive species observed and it had a low density (Table 3). Figure 1 illustrates that planted species density generally increased from 2007 to 2009, and *Carex utriculata* was the most successful planted species. No data were collected in 2008 and 2009 because the permanent transect could not be located in those years.

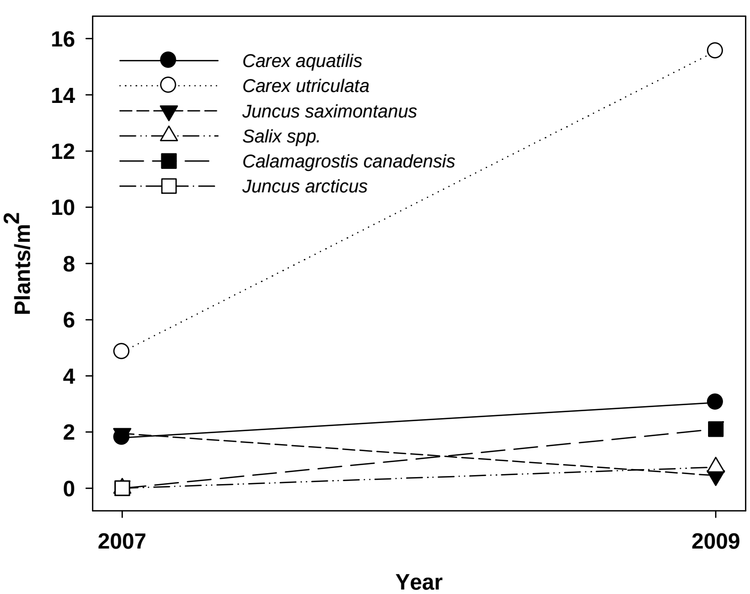

Fig. 2. Transect 1 planted species density over time

Table 3. Transect 1 species density and species richness.

PLANTED SPECIES INVASIVE EXOTIC SPECIES				
	Plants/m²			
SPECIES	**T1 2007**	**T1 2008[1]**	**T1 2009[2]**	**T1 2010[3]**
Carex aquatilis	1.80	.	3.05	.
Carex utriculata	4.85	.	15.55	.
Juncus saximontanus	1.95	.	0.45	.
Salix sp.	0	.	0.75	.
Calamagrostis canadensis	0	.	2.10	.
Juncus arcticus	0	.	Y	.
Potentilla fructicosa	N	.	0.05	.
Glyceria grandis	N	.	1.15	.
Antennaria spp.	N	.	0.35	.
Achillea lanulosa	N	.	0.05	.
Potentilla pulcherrima	N	.	0.15	.
Phleum pratense	N	.	0.75	.
Puccinella airoides	N	.	Y	.
Fragaria virginiana	N	.	0.05	.
Trifolium pratense	N	.	Y	.
Cerastium strictum	N	.	Y	.
Carex nebrascensis	N	.	Y	.
Total Species Richness	**3**		**17**	
Native Species Richness	**3**		**16**	
Non-native Species Richness	**0**		**1**	

[1] Could not find plot, stakes were gone
[2] Plot re-installed using GPS coordinates and photos
[3] Could not find rebar, no attempt to re-establish plot

Transect 2

Table 4 shows species densities surveyed in T2 along with species richness. All planted species increased in density except for *Juncus arcticus,* which has not become established in this plot. *Carex spp.* dominated the community over all four years. *Juncus saximontanus* and *Salix spp.* were established by 2009 and continued to increase in density through 2010. *Calamagrostis canadensis* has only become established recently with a density of 0.45 plants/m^2 in 2010. The invasive exotic grass, *Phleum pratense*, was also established in the plot in 2009, and it was the only invasive species observed.

Total species richness generally increased from three in 2007 to 11 in 2010. The only decrease was in 2008, when no *Salix* species were observed. Native species richness increased from three in 2007 to 10 in 2010, while non-native species richness of *P. pratense*, established in 2009 and remained present in 2010. Fig. 2 illustrates how *Carex* species have been successful in T2, especially with its dramatic increase from 2009 to 2010.

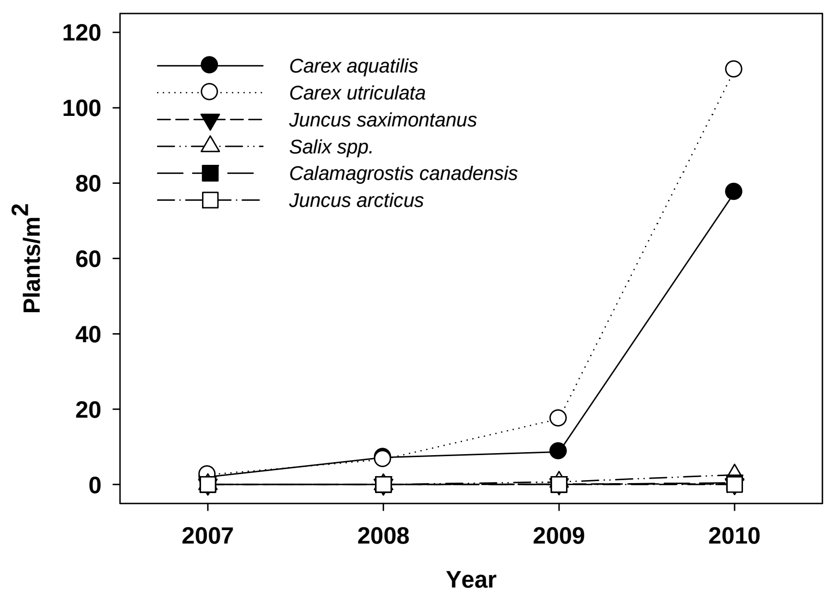

Fig. 3. Transect 2 planted species density over time

Table 4. Transect 2 species frequency and richness

PLANTED SPECIES				
INVASIVE EXOTIC SPECIES				
	Plants/m2			
SPECIES	**T2 2007**	**T2 2008**	**T2 2009**	**T2 2010**
Carex aquatilis	2.00	7.15	8.70	77.5
Carex utriculata	2.55	6.65	17.4	110
Juncus saximontanus	0	0	0.1	0.15
Salix spp.	0.05	0	0.65	2.55
Calamagrostis canadensis	0	0	0	0.45
Juncus arcticus	0	0	0	N
Glyceria grandis	N	0	1.3	Y
Phleum pratense	N	N	Y	Y
Puccinella airoides	N	N	Y	N
Trifolium pratense	N	N	Y	Y
Carex nebrascensis	N	N	Y	N
Juncus bufonius	N	N	Y	N
Populus tremuloides	N	N	N	Y
Agrostis gigantea	N	N	N	Y
Eleocharis acicularis	N	N	N	Y
Total Species Richness	**3**	**2**	**10**	**11**
Native Species Richness	**3**	**2**	**9**	**10**
Non-native Species Richness	**0**	**0**	**1**	**1**

Transect 3

Table 5 shows species and densities surveyed in T3 along with species richness. Of the planted species, *Salix spp.* and *Juncus arcticus* were the only two that increased in density. *Salix spp.* increased from 0.65 plants/m^2 in 2007 to 2.5 plants/m^2 in 2010. *J. arcticus* did not establish until 2009 with 1.55 plants/m^2, and increased to 2.50 plants/m^2 in 2010. *Juncus saximontanus* was present in T3 with one plant from 2007 to 2009, and no individuals observed in 2010. Neither *Carex* species nor *Calamagrostis canadensis* were observed in T3 from 2007 to 2010. Transect 3 supported *Acetosella vulgaris* and *Melilotus alba*; both non-native non-invasive species. *A. vulgaris* established in 2009, while *M. alba* established in 2010. The total species richness of T3 increased from two in 2007 to nine in 2010, native species richness increased from two in 2007 to seven in 2010 and non-native species richness increased to two between 2009 and 2010. Figure 3 illustrates how *Juncus arcticus* and *Salix spp.* densities increased beginning in 2008 and continuing through 2010.

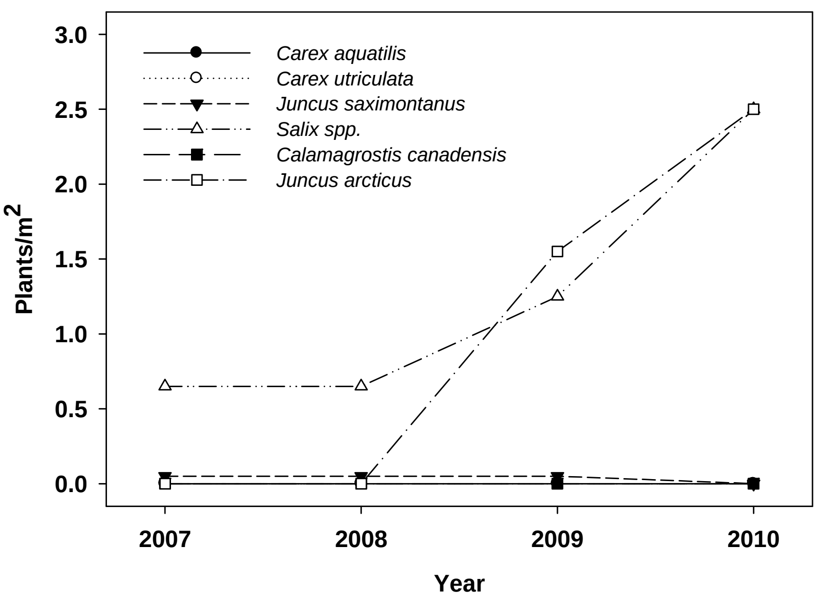

Fig. 4. Transect 3 planted species density over time.

Table 5. Transect 3 species frequency and richness

PLANTED SPECIES				
NON-INV EXOTIC*				
	Plants/m^2			
SPECIES	T3 2007	T3 2008	T3 2009	T3 2010
Carex aquatilis	0	0	0	0
Carex utriculata	0	0	0	0
Juncus saximontanus	0.05	0.05	0.05	0
Salix spp.	0.65	0.65	1.25	2.50
Calamagrostis canadensis	0	0	0	0
Juncus arcticus	0	0	1.55	2.50
Cerastium strictum	N	N	Y	N
*Acetosella vulgaris**	N	N	Y	Y
Penstemon virens	N	N	Y	Y
Carex spp.	N	N	N	Y
Poa compressa	N	N	N	Y
Agrostis gigantea	N	N	N	Y
*Melilotus alba**	N	N	N	0.05
Agrostis scabra	N	N	N	Y
Total Species Richness	**2**	**2**	**6**	**9**
Native Species Richness	**2**	**2**	**5**	**7**
Non-native Species Richness	**0**	**0**	**1**	**2**

Transect 4

Table 6 shows both species percent cover and density for T4. Due to different data collection methods being used in different years (cover in 2007 and 2008, density in 2009 and 2010), it was not clear in all cases whether density increased over time, except if a species started or ended at a value of zero. For instance, *Carex utriculata* (45% cover in 2007, 10% cover in 2008 and 0% cover in 2009 and 2010) and *Juncus saximontanus* (2% cover in 2007 and 0% all following years) both had no individuals present in the transect in 2010, therefore, these species presumably decreased in density. *Calamagrostis canadensis* was not observed in T4 and *Juncus arcticus* was observed in 2010 at a density of with no count recorded. *Carex aquatilis* increased in percent cover with 45% in 2007 and 70% in 2008 while density increased from 119 plants/m^2 in 2009 to 128 plants/m^2 in 2010, so it is reasonable to assume an increase in plot density for *C. aquatilis*. *Salix spp.* percent cover increased from 5% in 2007 to 10% in 2008, but density decreased from 4.6 plants/m^2 in 2009 to 3.5 plants/m^2 in 2010. *Phleum pratense*, an invasive exotic, was only present in 2009 and *Poa pratensis*, a non-invasive exotic, was present in 2010. Total species richness increased from seven species in 2007 to ten in 2010. Native species richness followed a similar trend, increasing from seven in 2007 and to nine species in 2010. A single non-native species was present in both 2009 and 2010.

Table 6: Transect 4 Species Percent Cover (2007 & 2008) or Density (plants/m^2) (2009 & 2010)

PLANTED SPECIES / INVASIVE EXOTIC SPECIES / NON-INV EXOTIC				
SPECIES	**T4 2007**	**T4 2008**	**T4 2009**	**T4 2010**
Carex aquatilis	45%	70%	119	127.75
Carex utriculata	45%	10%	0	0
Juncus saximontanus	2%	0%	0	0
Salix sp.	5%	10%	4.60	3.45
Calamagrostis canadensis	0	0	0	0
Juncus arcticus	0	0	0	Y
Potentilla fructicosa	1%	0%	N	N
Glyceria grandis	1%	0%	0.30	N
Anaphalis margaritaceae	1%	0%	N	Y
Antennaria spp.	N	N	Y	N
Achillea lanulosa	N	N	Y	N
Potentilla pulcherrima	N	N	Y	N
Phleum pratense	N	N	Y	N
Fragaria virginiana	N	N	Y	N
Trifolium pratense	N	N	N	Y
Populus tremuloides	N	N	Y	Y
Mertensia spp	N	N	Y	N
Clemetsia rhodantha	N	N	Y	N
Agrostis gigantea	N	N	N	Y
Poa pratensis	N	N	N	Y
Sedum rhodantham	N	N	N	Y
Antennaria parvifolia	N	N	N	Y
Total Species Richness	**7**	**3**	**11**	**10**
Native Species Richness	**7**	**3**	**10**	**9**
Non-native Species Richness	**0**	**0**	**1**	**1**

Total Planted Species

Table 7 shows the total planted species counts of T1, T2 and T3. The two *Carex* species were the most abundant of all six planted species in each year, while *Juncus saximontanus* was relatively scarce with total indivduals decreasing from forty to three in 2007 and 2010, respectively. *Salix spp.* gradually increased from 14 individuals observed in 2007 to 101 in 2010. *Calamagrostis canadensis* and *Juncus arcticus* were not observed in any of the plots until 2009. *C. canadensis* decreased nearly five-fold between 2009 and 2010, from 42 plants to 9 plants, while *J. arcticus* counts increased about 1.5 times from 2009 to 2010.

Table 7. Total Planted Species Counts

SPECIES	2007	2008	2009	2010
Carex aquatilis	76	143	235	1550
Carex utriculata	148	133	659	2200
Juncus saximontanus	40	1	12	3
Salix sp.	14	13	53	101
Calamagrostis canadensis	0	0	42	9
Juncus arcticus	0	0	31	50

DISCUSSION

Planted Species Success

Carex species

Comparing all three transect trends for the planted species, it seems that the *Carex* species established quite well, especially in the wetter plot of T2. Although we have no data for T1 in 2008 and 2010, by looking at Table 3 and Fig. 1, it seems that the *Carex* species became established and increased in density, especially *Carex utriculata*. The USDA, has not given *C. utriculata* a wetland species designation in the intermountain region of Colorado (Region 8) but it thrived in the wetter plot, T2.

C. aquatilis is designated as an obligate wetland species (occurs in wetlands almost always; estimated probability 99%) by the USDA, but it was not as abundant as *C. utriculata* was.

Salix spp.

The *Salix* species survived well in all three transects, but were most abundant in T3. *Salix* species became established later in T1 and T2, possibly because the habitat had been disturbed by high volumes of running water from the nearby creek, hindering establishment. The USDA's designation for most *Salix* species are obligate wetland or facultative wetland (estimated probability 67%-99%, occasionally found in upland sites). The nine willow species used for revegetation all occur in an adjacent willow carr, and most *Salix* species in R8 are designated as obligate or facultative wetland species.

Juncus arcticus

The only other species that established fairly well was *Juncus arcticus* and this was apparent only in T3. *J. arcticus* became established in 2009 and increased in density quite rapidly compared with the other species within the plot. In T1, *J. arcticus* presence was noted starting in 2009 but no count could be performed in 2010. In T2, *J. arcticus* did not become established. The USDA designates *J. arcticus* as a facultative wetland species.

Juncus saximontanus

Juncus saximontanus did not establish well in any transect. In T2 and T3, densities were quite low, and in the wetter T1 density was initially relatively high but dropped off by 2009. The USDA designates *J. saximontanus* as a facultative wetland species.

Calamagrostis canadensis
Calamagrostis canadensis has become established in wetter plots, but with both low density. Only in the wettest transect of T1 was *C. canadensis* observed at a density greater than 1 plant/m^2, and was not observed at all in the dryer transect T3 (Table 5). The USDA designates *C. canadensis* as an obligate wetland species, which likely explains its denser establishment in T1.

Invasive species presence has been limited to *Phleum pretense* in T1 and T2. Future data collection should include a count of invasive non-natives to more closely monitor the progress of this common invasive species as well as other newly recruited invasive species.

The hydrology of the Fan Lake restoration area likely had an effect on what species have become established in each transect, although no definite pattern of establishment was apparent in relation to USDA wetland species designations. Transects 1 and 2, the wetter sites, supported the greatest number of planted species, including the obligate wetland species *Calamagrostis canadensis*. Transect 3 supported the fewest planted species, possibly due to the dryness of that site and the status of all of the planted species as obligate or facultative wetland species. Also, herbivory likely did not affect plant establishment as the area was fenced off to exclude elk (*Cervus canadensis*).

Future wetland studies should incorporate the use of longer lengths of rebar to establish permanent transects in an attempt to avoid stakes being washed away or buried under sediment during periods of high water, which is the likely cause of the loss of T1.

LITERATURE CITED

Cooper, D.J. and E.A. Gage. 2006. Fan Lake and Fall River Restoration: Site Characterization, Design, and Recommendations. Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, CO. p27.

HIDDEN VALLEY WETLAND RESTORATION
2006-2010 RESTORATION MONITORING REPORT

INTRODUCTION

Hidden Valley has historically been a cultural and recreational area since the 1930's. Construction of Trail Ridge Road allowed access to this area for backcountry winter sports, and in 1955, after widespread use and mounting pressures, the area was converted into a commercialized ski resort. The ski area was a popular and affordable attraction for Rocky Mountain National Park (RMNP) visitors for many years; however harsh weather conditions, development restrictions and the growing popularity of other ski resorts eventually led to the decline of the ski area. In 1992 the Hidden Valley Ski Resort ceased operations due to non-renewal of their contract with the Park. In 1993 a restoration plan was developed and the long road of rehabilitation began.

In the summer of 1999 deconstruction of the resort began. Concrete ski lift pads were removed, slopes were recontoured and streams were restored. Extensive restoration efforts were conducted throughout the entire area in the subsequent six years. The final stage of the Hidden Valley project began in 2005 with the restoration of the wetland habitat. The use of aerial photos and the study of contemporary and historic water table levels were used to determine how to best excavate and re-contour the site to restore it to the appropriate native wetland conditions.

In 2006, the Wildlands Restoration Volunteers, a group of 60 people, worked with the resource stewardship division with the restoration the wetland vegetation. A total of 18,780 plants were planted in both wetland and upland habitats. Planted species included: 10,000 *Juncus articus*, 3,300 *Calamagrostis canadensis*/*Poa palustris*, 5,100 *Carex spp*., 250 *Salix spp*., 300 *Fragaria spp*., and 90 *Juncus saximontanus*. Willow (*Salix* spp) stakes were cut from the adjacent willow carr and the remainder of the plants were propagated from native seed in the RMNP greenhouse.

In order to survey the progress of the wetland restoration, a monitoring program was established to evaluate the success of this restoration effort and identify the need for potential follow-up treatments. The purpose of this monitoring program was to monitor the success of the restoration efforts, as well as to record the progress of natural regeneration, native recolonization and exotic species invasions.

MATERIALS & METHODS

The area of the wetland restoration site was approximately 0.6 ac. Two 20 m^2 (2 m by 10 m) belt transects were permanently installed in the restoration site by hammering rebar stakes into the ground at each corner of a transect. Transects were placed within the wetland in locations that appeared to adequately capture vegetation restoration efforts throughout the wetland (Fig. 1 & 2). GPS coordinates of the northwest corner stake of each transect were recorded using a handheld Garmin Hcx GPS unit in the NAD83 datum setting and are listed below (Table 1). Additionally, transect photos were taken from the north side of each transect each year data were collected.

Table 1. UTM Coordinates for belt transects in the Hidden Valley restoration site. (Datum: NAD 83)

Transect	UTMN	UTME
T1	0444535	4471769
T2	0444552	4471797

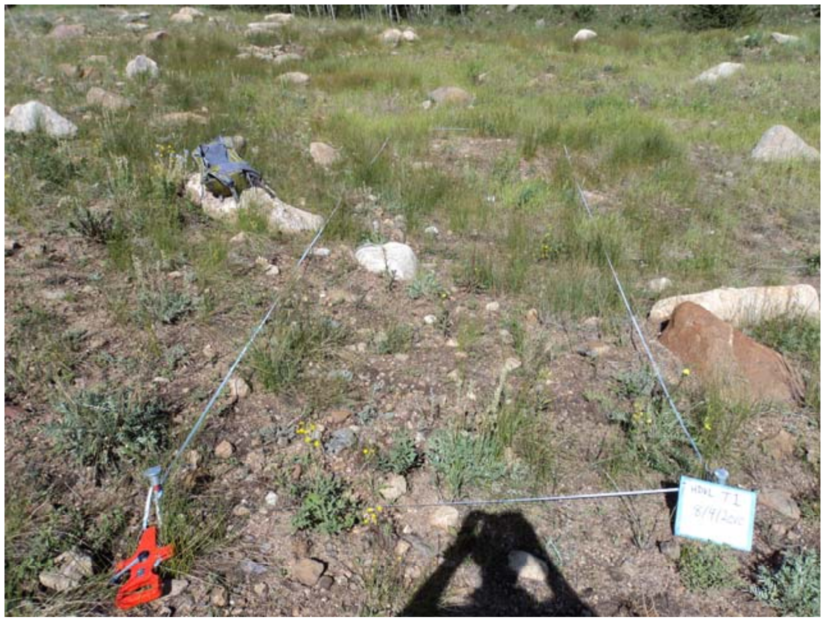

Fig 1. Belt transect 1 in Hidden Valley wetland restoration site (2010).

Fig. 2. Belt transect 2 in Hidden Valley wetland restoration site (2010).

In each transect, the presence of all species within the belt transect was recorded and the number of individuals of each of the seven planted species was counted. The number of individuals of all non-native species found within each transect was also counted so that their presence could be closely monitored. The status of a species as native or non-native was based on its classification in Weber's Colorado Flora of the Eastern Slope guide (2001). Within each transect, individual plants were counted for *Carex spp.*, *Calamagrostis canadensis*, *Salix spp. Juncus articus*, *Juncus saximontanus*, *Fragaria spp.*, and *Poa palustris* as well as any species classified as non-native. *Poa palustris*, a native grass, was not included in the original vegetation plan, but was planted as a result of misidentified seed that was incorrectly classified as *Calamagrostis canadensis*. Data collection dates for this study are shown below (Table 2).

Table 2. Data collection dates for Hidden Valley Restoration monitoring plots. 2007 collection time was no recorded.

Year	Collection date
2006	Early Oct.
2007	No record
2008	Sep.
2009	Early Aug.
2010	Early Aug.

Individual plant count data were used to evaluate changes in yearly species densities and species presence data were used to assess changes in yearly species richness and composition. Density values for Transect 1 and 2 were averaged, standard error was calculated and these were plotted over time. Statistical tests were not possible due to limited degrees of freedom, thus, all evaluation is qualitative. Wetland indicator status of plant species was based on the USDA PLANTS database classifications for the intermountain region of Colorado (Region 8, or R8). A species was considered a wetland species if it was classified as an obligate (99% probability of wetland occurrence) or facultative (67-99% probability of wetland occurrence) wetland species.

RESULTS

Planted Species

Over the course of this monitoring study all planted species, except for *Juncus saximontanus*, increased in density in at least one transect. There were no *J. saximontanus* plants observed during any survey year.

Calamagrostis canadensis density increased over the course of the study; it was more abundant in Transect 2 (T2) than in Transect 1 (T1). *C. canadensis* density was 22 times greater in T2 than in T1 in 2009, but that difference was reduced to two times as great in 2010 (Fig. 3).

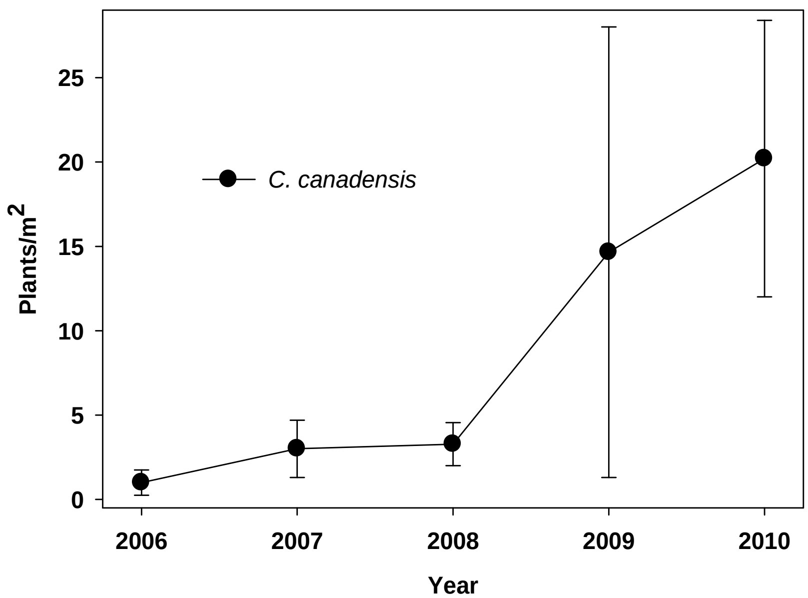

Fig. 3. Density of *Calamograstis canadensis* in the Hidden Valley Wetland restoration site (mean ± 1 standard error of the mean).

Plot density of *Juncus arcticus* averaged 3 plants/m^2 from 2006 to 2010, but increased markedly in 2010 to 238 plants/m^2 (Fig. 4). *J. arcticus* had greater densities in T1 for all years of data collection.

Poa palustris density increased over time, but was generally observed in greater densities in only one plot for each survey year, except in 2008 when plot densities were nearly equivalent (Fig. 5). Density data were not collected in 2009, though *P. palustris* was noted as present in both T1 and T2 that year. Density differences between plots were inconsistent, with greater densities of *P. palustris* observed in T2 in 2006 and 2007 and greater densities in T1 in 2010.

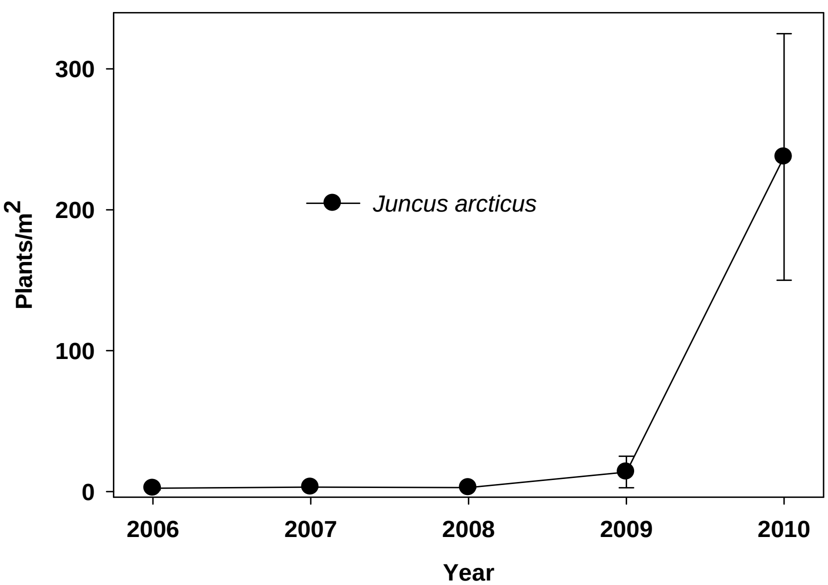

Fig. 4. Density of *Juncus arcticus* in the Hidden Valley Wetland restoration site (mean ± 1 standard error of the mean).

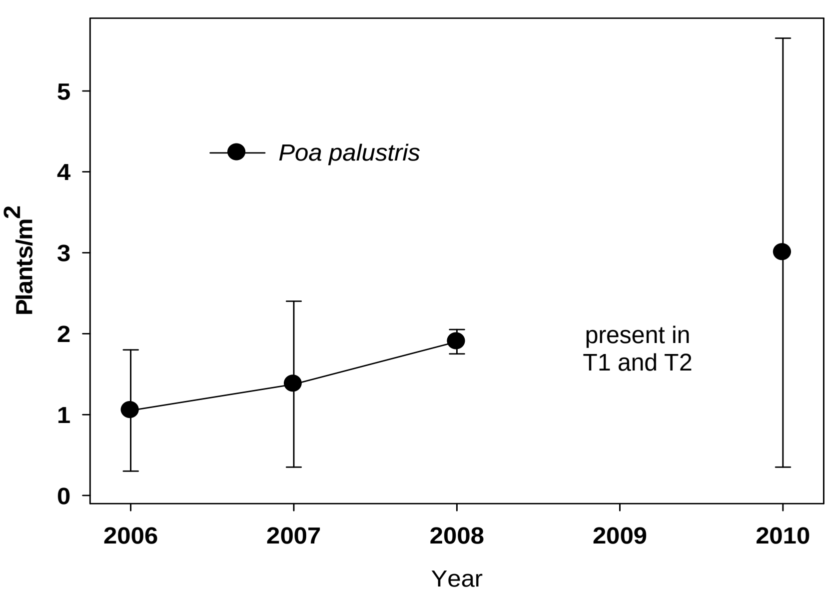

Fig. 5. Density of *Poa palustris* in the Hidden Valley Wetland restoration site. Although no density data were collected in 2009, *P. palustris* was noted as present in both transects (mean ± 1 standard error of the mean).

Carex species density averaged 3.7 plants/m^2 from 2006 to 2009 and increased to 83 plants/m^2 in 2010 due to increased density in T2 (Fig. 6). *Carex* density was greater in T2 compared to T1 in all survey years, and was 194 times greater in T2 in 2010.

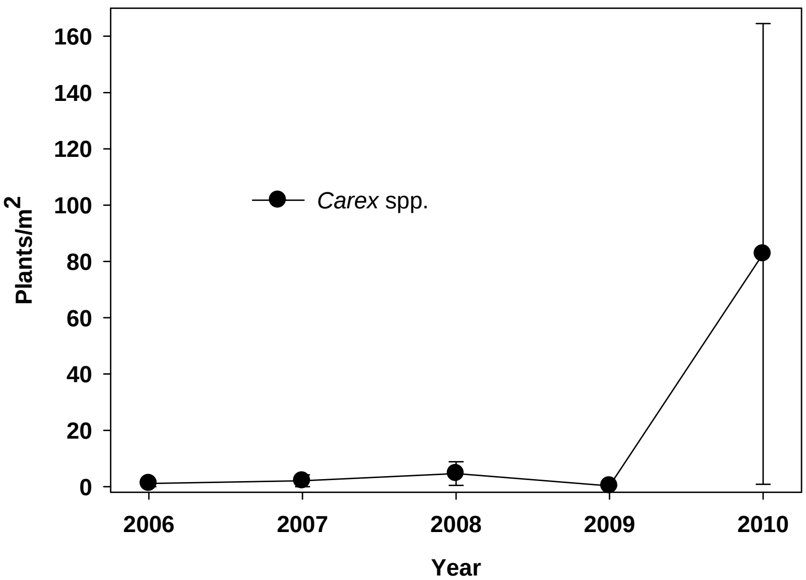

Fig. 6. Density of *Carex* species in the Hidden Valley Wetland restoration site (mean ± 1 standard error of the mean).

Salix species density was greatest in T2 for all years, with the greatest number of *Salix* present in T1 being a single plant in 2007 and 2010 (Fig. 7). *Salix* density increased from an average of 0.10 plants/m^2 in 2006 through 2007 to 0.46 plants/m^2 in 2007 through 2010.

Fragaria species density increased from 2008 to 2010, with densities being greater in T1 for each survey year (Fig. 8).

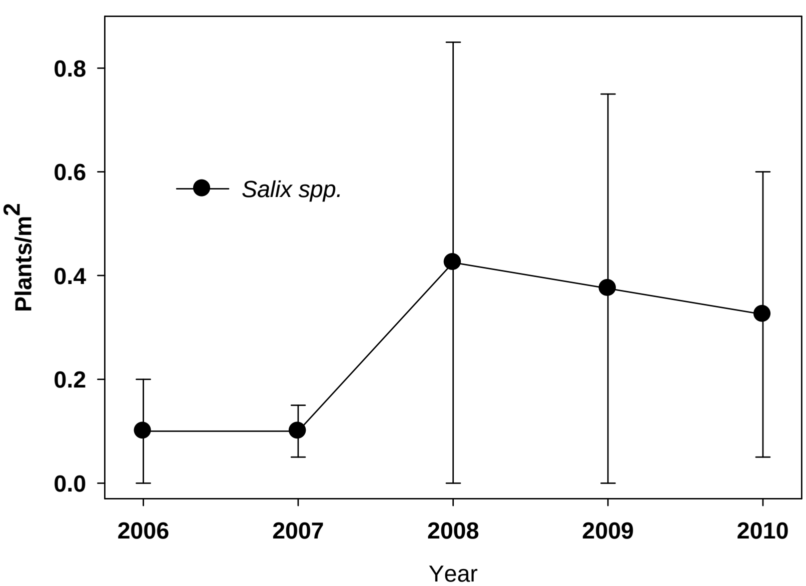

Fig. 7. Density of *Salix* species in the Hidden Valley Wetland restoration site (mean ± 1 standard error of the mean).

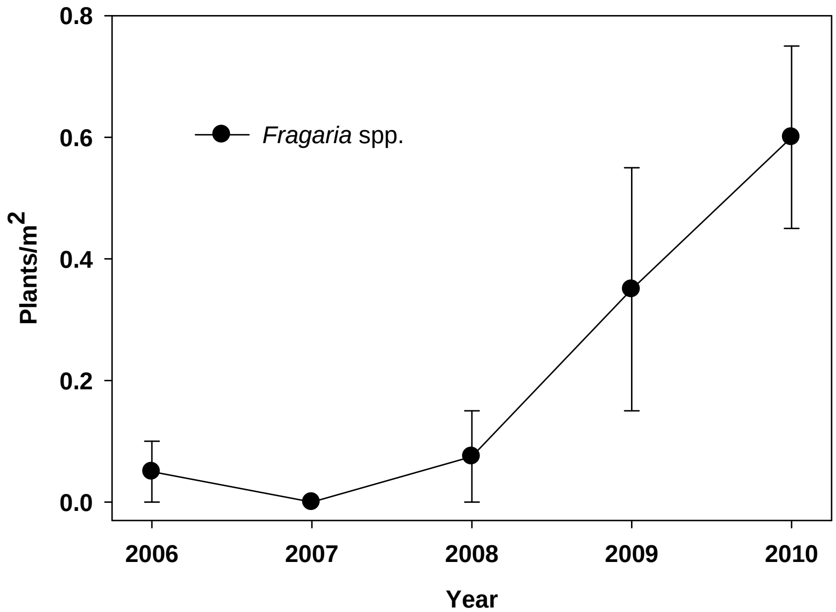

Fig. 8. Density of *Fragaria* species in the Hidden Valley Wetland restoration site (mean ± 1 standard error of the mean).

Invasive Species

Species richness of invasive species remained constant at approximately two invasive species observed per year (Table 3). *Bromus inermis* was present every year, and was only observed in T1. Density of *B. inermis* in 2010 was 0.88 plants/m^2. *Bromus tectorum* was observed in T1 in 2009 and 2010, and only a single plant was observed in 2010. *Melilotus* spp. was present in 2006 and 2007, but has not been observed within either transect after 2007. Invasive species density data were not collected for most years, so an analysis of density changes was not possible.

Table 3. Species richness of all species (total), planted species, invasive species and obligate and facultative wetland species (wetland) in the Hidden Valley wetland restoration site.

Species	2006	2007	2008	2009	2010
Total	16	24	25	25	32
Planted	6	6	6	6	6
Invasive	2	2	1	2	2
Wetland	4	3	4	3	5

Species Richness

Total species richness has increased 100% over the course of this study (Table 3), with T2 having an average of approximately six fewer species than T1 per year. Planted species richness for both transects was the same for all years, with only *Juncus saximontanus* not observed in either plot. Wetland species richness averaged approximately four species per year. There was no difference between T1 and T2 in wetland species richness. Invasive species richness is discussed in the invasive species results sub-section.

DISCUSSION

This study indicates that transplanted wetland species have successfully become established in the Hidden Valley Wetland restoration area. The only planted species that was not observed in either monitoring transect was *J. saximontanus*. Although most planted species had become successfully established in both transects, the level of species success varied between T1 and T2, and is likely due to a difference in the hydrology of each monitoring site as T2 was designed as a wetland target community, and T1 as an upland transitional community. As shown in Fig. 1 and 2, T1 was located in an area that was drier than T2, and pictures of these plots from 2008 confirm this, as standing water can be seen in T2 and not T1 both years. *Calamagrostis canadensis*, *Salix* spp. and *Carex* spp. were more abundant in T2, while *J. articus* and *Fragaria* spp. were more abundant in T1 and *P. palustris* showed no preference to either transect. Of the more abundant T2 planted species, *C. canadensis* is listed as an obligate wetland species, and while the specific species of planted *Salix* and *Carex* are not known, we classified them as facultative wetland on the basis that most species of these genera are either obligate or facultative wetland species in CO Region 8. The more abundant T1 planted species *J. arcticus* and *Fragaria* spp. are listed as facultative wetland and facultative upland, respectively. The presence of *Fragaria* spp., the only planted upland species, in greater densities in T1 suggests that T1 is located in a drier area of the wetland restoration site when compared to T2. There were no differences in species richness of recruited wetland or upland species between transects.

Invasive species in both plots were limited to three total species, with *Melilotus* spp. being eradicated from this site by manual removal in 2008. *Bromus inermis* was the most persistent invasive species. It was present in all 5 yrs of monitoring, and is a common invasive species in the surrounding Hidden Valley recreation area, likely the result of this species having been planted in the past for ground cover. The appearance of *Bromus tectorum* in 2009 and 2010 is significant, as this grass is highly invasive in disturbed sites and can out-compete native species for resources. Although only one plant was observed in 2010, *B. tectorum* is a prodigious producer of seed and could spread rapidly through this site in the future, potentially making future (bi-yearly) invasive species monitoring a priority at this site.

Literature Cited

Weber, W.A and R.C. Wittmann. 2001. Colorado Flora Eastern Slope 3rd ed. Boulder (CO). University Press of Colorado.

BEAR LAKE ROAD PHASE I
2006-2010 RESTORATION MONITORING REPORT

INTRODUCTION

Phase one of the Bear Lake Road reconstruction was completed in 2004. This reconstruction involved relocation of parking areas and the resurfacing, straightening, and widening of the road to accommodate large buses and RVs. The construction created large disturbances along the road from the entrance to Glacier Basin Campground and the Park and Ride south to the Bear Lake parking lot.

Following completion of road construction, restoration efforts began in the disturbed areas. Disturbances caused by pullout and parking lot removal were prepared by amending the native soil with top soil. These areas were then planted using greenhouse propagated stock and some salvaged plants. The steep roadside slopes along Bear Lake Road were a challenge to revegetate and were restored using several seeding treatments. The slopes were first hydroseeded with sterile wheatgrass in the fall of 2004 to help stabilize the slopes until a native seed source could be introduced. In the 2005 season, attempts at planting the slopes using live plant stock were made but were not feasible due to the adverse working conditions and safety concerns. Before the first snowfall of 2005, slash and duff were spread over the disturbed slopes to prepare the soils for additional treatment the following year. In May of 2006, the first hydroseeding treatment was applied to reintroduce several native species to the plots, and a second hydroseeding treatment was applied to the site in October 2006.

Many of the disturbances along the roadway received some type of restoration effort including planting, hydroseeding or salvaged topsoil replacement. To evaluate the effectiveness of each restoration method, three monitoring plots were established in restoration sites; one plot was placed in an area restored using hydroseeding, another using planting, and the third using topsoil replacement.

METHODS

Restoration Sites

BLR_001
This site was hydroseeded with sterile wheatgrass in the fall of 2004 to stabilize the disturbed soils and hydroseeded again with a native species seed mix in May and October of 2006. BLR_001 is located at an elevation of approximately 8600 ft on a large southeast facing slope with no canopy cover and there is a stand of lodge pole pine located on the northeast edge of the restoration site.

*BLR*_002
This site was restored by replacing topsoil that had been salvaged from the site prior to road construction. No revegetaion efforts were made here and the site was allowed to revegetate naturally after topsoil replacement. The restoration site is located at an

elevation of approximately 8900 ft on a small north facing slope with more tree cover than the other two sites and is in close proximity to the roadside.

BLR_003
The third restoration site was formerly a parking lot, and received the most intensive restoration efforts. The soil was amended with salvaged topsoil and revegetated with greenhouse stock and salvaged plantings. This site is on a south facing slope with no canopy cover at an elevation of approximately 9250 ft.

Table 1. GPS locations of monitoring transects.

Bear Lake Road Phase I		Datum: NAD83
Transect	UTME	UTMN
BLR_001	449066	4464438
BLR_002	446928	4463486
BLR_003	445326	4462186

Monitoring

Permanent monitoring transects were installed at each site by hammering a length of rebar and a wooden stake into the ground 30 meters apart. A 100 m measuring tape was stretched between the zero and 30 m stakes for data collection with the zero meter point of the tape at the rebar stake. GPS coordinates were recorded for the zero meter point of the transect in NAD83 datum. Each year data were collected, a photograph of each transect was taken from the zero meter and 30 m viewpoints.

Along each transect, line-point intercept data were collected at every tenth of a meter (decimeter) for the entire length of the transect. A narrow (~1 cm diameter) survey pole was dropped straight to the ground at each decimeter along the transect, and each species of plant that touched the survey pole was recorded in addition to any rock, litter and bare soil that the pole contacted. These data were then used to calculate the total percent cover and relative percent cover of each species and plant group (native species, non-native species, etc.) recorded.

Square meter plot data were also collected at three points along each transect. Each individual plant of each species within the square meter quadrat was counted. These data were used to calculate the plot density of each plant species and plant group present in the transect.

After transect data were collected, the data were entered into an Excel spreadsheet and organized by growth habit and designation as a native species, a non-native invasive species or a non-native non-invasive species. The possible growth habit categories were tree, shrub, grass or grasslike species (including rush and sedge species) (GGS), forb, or moss and lichen. Species were classified as having a particular growth habit based on their designation in the USDA PLANTS profile database and were classified as native or non-native based upon their designation as such in Weber's <u>Colorado Flora of the Eastern Slope</u> guide (2001). Species were classified as invasive if they were listed on Rocky Mountain National Park's list of invasive species or the Colorado Department of Agriculture's schedule of noxious weeds.

Since the monitoring plots were installed in restoration sites that varied significantly from each other in habitat, elevation, aspect, slope and restoration method, the site data were summarized and discussed individually and not as replications of a single restoration study.

See appendices 1 and 2 for detailed information on how data were collected and analyzed over the course of this study.

RESULTS/DISCUSSION

BLR_001

From 2006 to 2010, percent cover of native grasses increased 35% and percent cover of native forbs increased 25% (Fig. 1). Relative cover of native grasses and forbs increased 20 and 12 percent, respectively. Density of native grasses varied from year to year, averaging 9.2 plants/m^2 through 2009. Density of native forbs increased 70-fold from 2006 to 2010. No native shrub or trees species were observed in line-point intercept or square meter transect data (Fig. 2).

No native grass square meter plot data were collected in 2010. The protocol for data collection in these plots specified that no counts were to be made for grasses, so only their presence was noted. Native grass species richness did increase, however from two in 2006 to five in 2010.

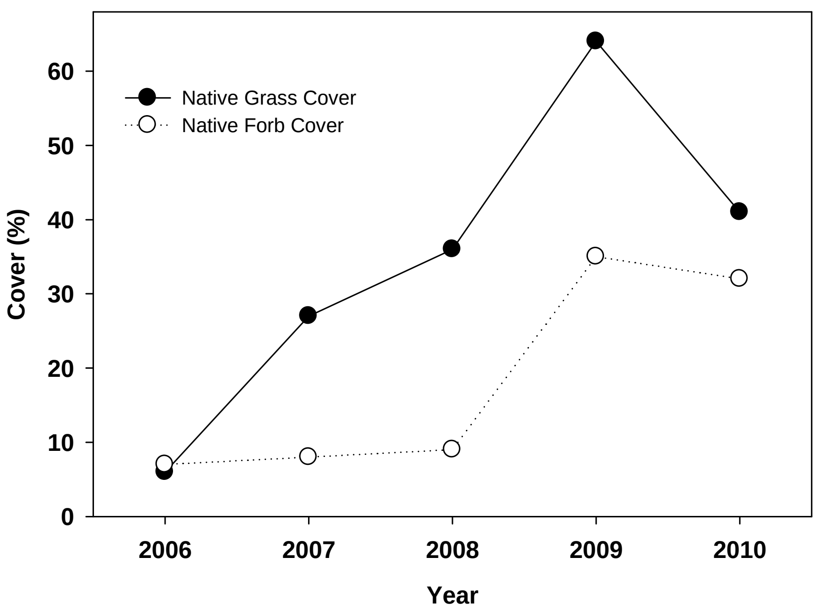

Fig.1. Percent cover of native grass and forb species in BLR_001 transect (hydroseed treatment).

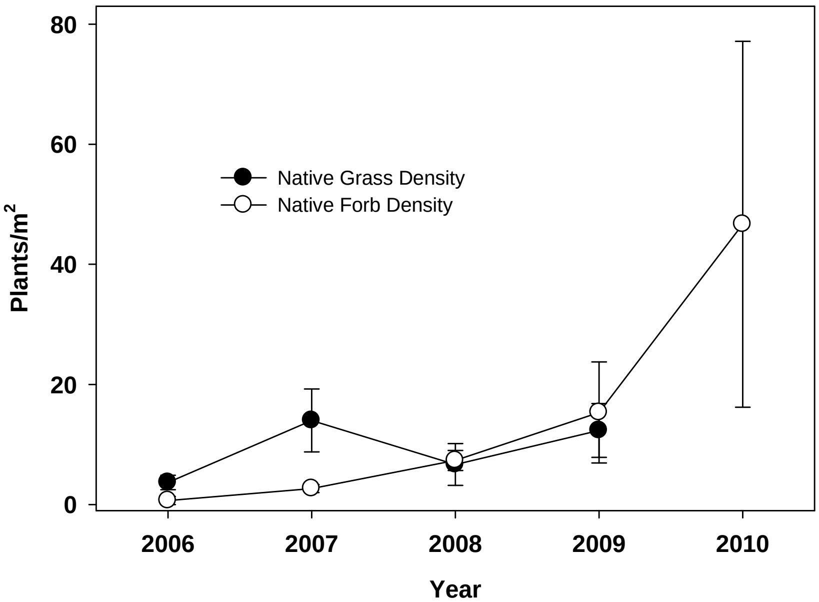

Fig.2. Density of native grass and forb species in BLR_001 transect (hydroseed treatment) (mean ± 1 standard error of the mean of the mean).

From 2006 to 2010, percent cover of non-native invasive grasses fell by 2% (Fig. 3), and relative cover fell from 13% to 1%. Invasive grass density remained low throughout the study, with the primary species being *Poa pratensis*. Percent cover of non-native, non-invasive forbs fell 7% to zero, with a peak in 2009 due to *Acetosella vulgaris* being present in high numbers. Non-native invasive and non-invasive forb density declined to nearly zero by 2010, with a 26% decrease in the non-invasive *Acetosella vulgaris* from 2008 to 2010 (Fig. 4).

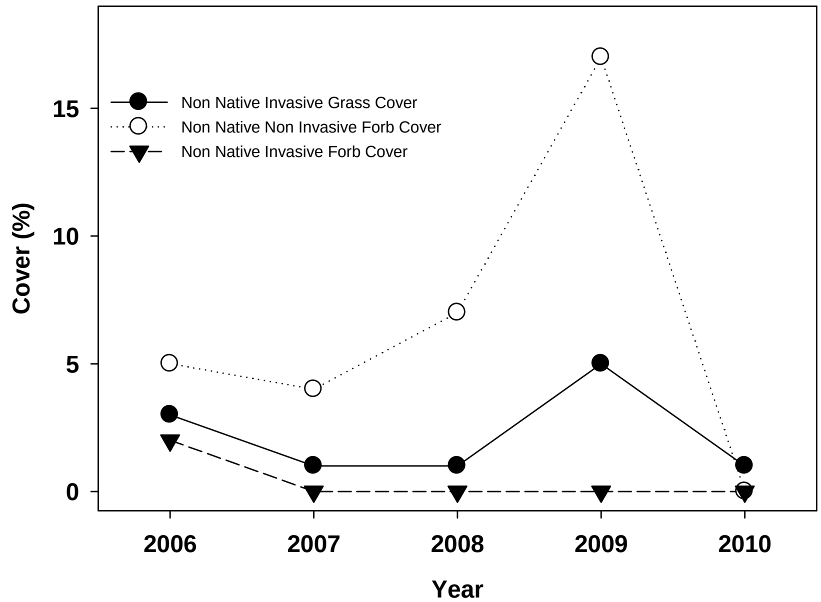

Fig.3. Percent cover of non-native grass and forb species in BLR_001 transect (hydroseed treatment).

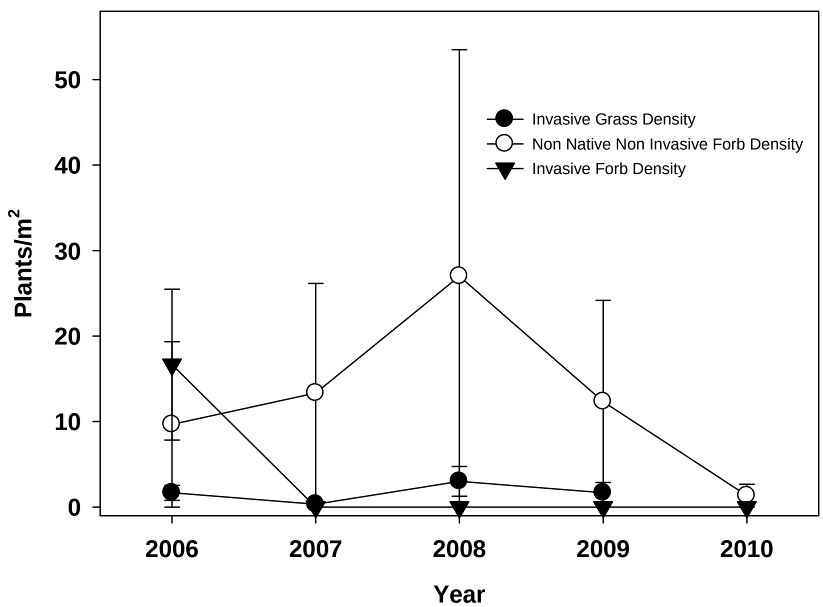

Fig.4. Density of non-native grass and forb species in BLR_001 transect (hydroseed treatment) (mean ± 1 standard error of the mean of the mean).

By 2010, total native species cover and all species cover increased to 74 and 75 percent, respectively, and non-native species comprised only 1% of the ground cover (Fig. 5). Bare ground cover in 2010 was 15%. Native species density increased more than ten-fold, while non-native, non-invasive species density increased to a peak of 27 plants/m^2 in 2008 and subsequently decreased to 0 plants/ha in 2010 (Fig. 6). This drop in overall non-native, non-invasive species density is primarily due to the decline in *Acetocella vulgaris* density. The percent cover data and density data suggest that from 2006 to 2010 native species were well established and increasing in cover and density, while invasive species may be in decline. This area has been treated by the exotics crew for the control of invasive grasses, which may be a factor in the decline in invasive grass cover.

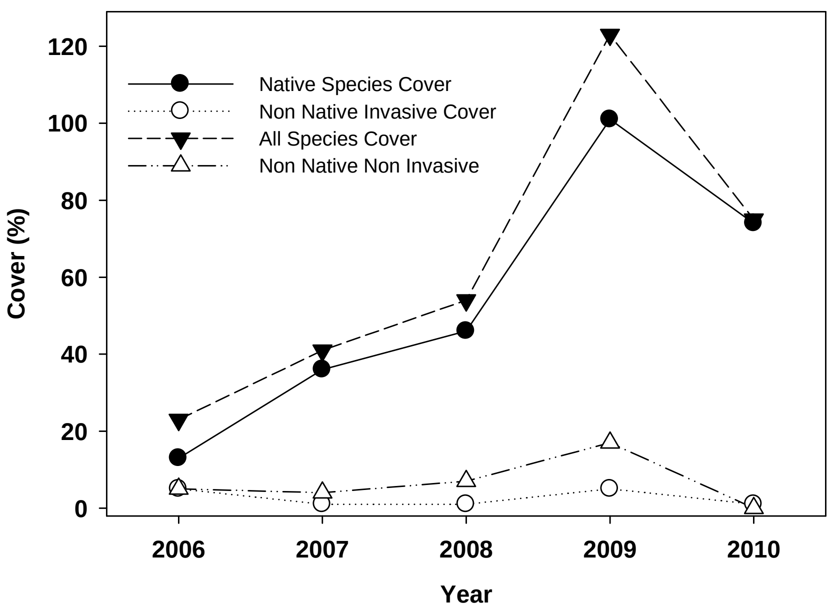

Fig.5. Percent cover of native, non-native and all species in BLR_001 transect (hydroseed treatment).

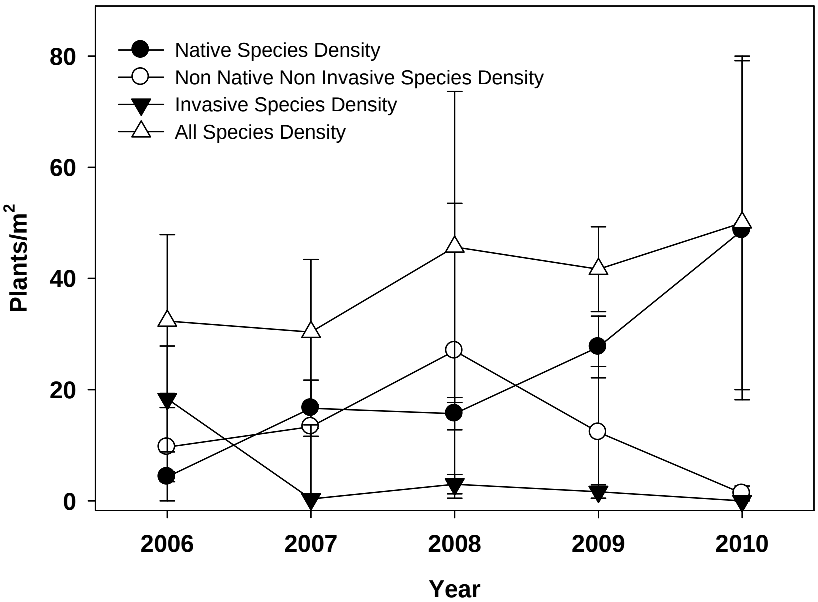

Fig.6. Density of all native, non-native, invasive and total species in BLR_001 transect (hydroseed treatment) (mean ± 1 standard error of the mean of the mean).

Hydroseeded species success

For species included in the hydroseed mix, species richness remained at approximately three species present in both line-point intercept and square meter plot data for the entire duration of plot monitoring. In 2010, the combined relative cover of hydroseeded species was 12%, and the combined density of hydroseeded species was 6 plants/m^2. The only species that was observed for more than two data collection years was *Achillea lanulosa* (also recorded as *Achillea millefolium*, a morphologically identical variant). *Achillea lanulosa* comprised 8% of the relative cover in 2010, the highest of any of the seeded species. The only other species observed for more than one year was *Heterotheca villosa*, which had an average 2.2% relative cover. See Appendix 3 for table of all seeded species data.

BLR_002

Percent cover of native grasses increased 21% and percent cover of native forbs increased 4% from 2006 to 2010 (Fig. 7). Relative cover of native grasses and forbs increased 42 and 4 percent, respectively. Density of native grasses increased 3-fold in 2009 (Fig. 8). Species richness for native grasses in 2010 was seven, which is greater than native grass species richness values in previous years. Density of native forbs increased nearly three-fold from 2008 to 2010 (Fig. 8).

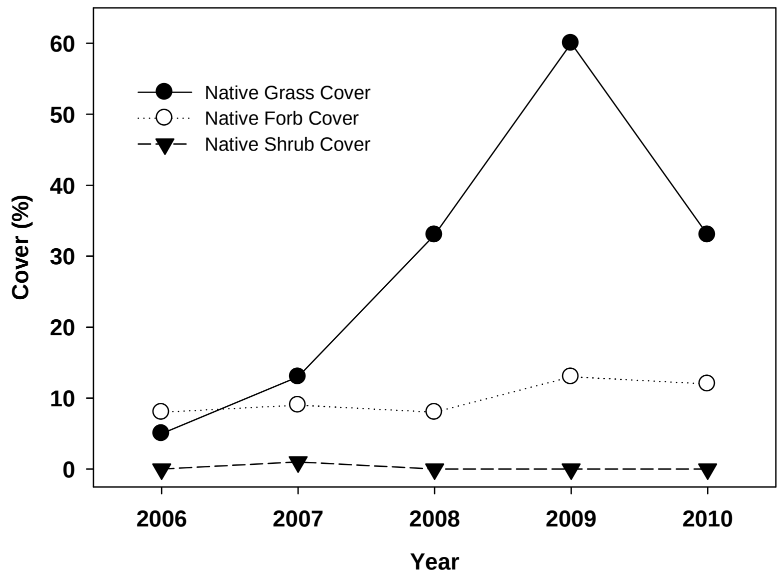

Fig.7. Percent cover of native grass and forb species in BLR_002 (salvaged topsoil treatment).

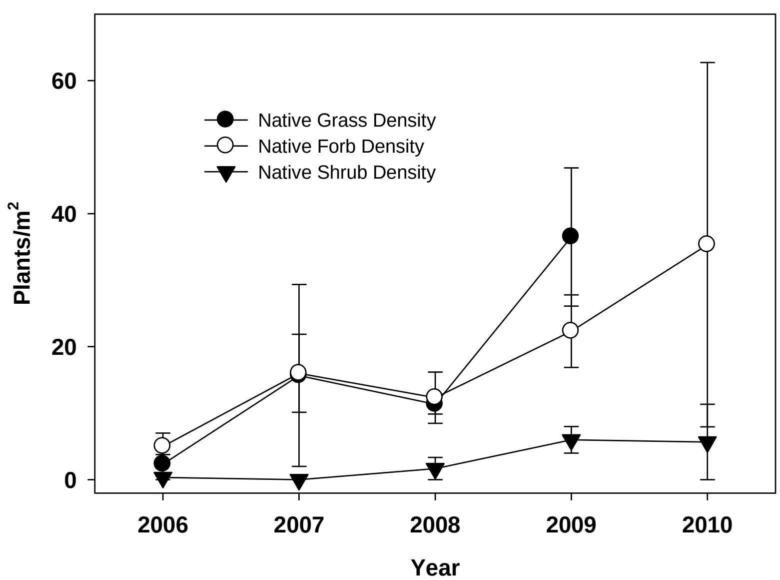

Fig.8. Density of native grass, forb and shrub species in BLR_002 (salvaged topsoil treatment) (mean ± 1 standard error of the mean of the mean).

Non-native, non-invasive forb cover and non-native, invasive forb cover both decreased to zero in 2010 with a large drop in cover of the non-invasive forb *Acetosella vulgaris* in 2008 (Fig. 9). Non-native, non-invasive forb density has decreased approximately six-fold over the course of the monitoring study (Fig. 10). Non-native, invasive grass cover averaged 8% between 2007 and 2009, with *Bromus tectorum* being the predominant invasive grass species. No invasive grass species cover was observed in 2010. Density of invasive grass species remained consistent from 2007 to 2009 and averaged 4.2 plants/m^2. Again, the most common invasive grass species in these plots was *Bromus tectorum*. No invasive grass density data were collected in 2010.

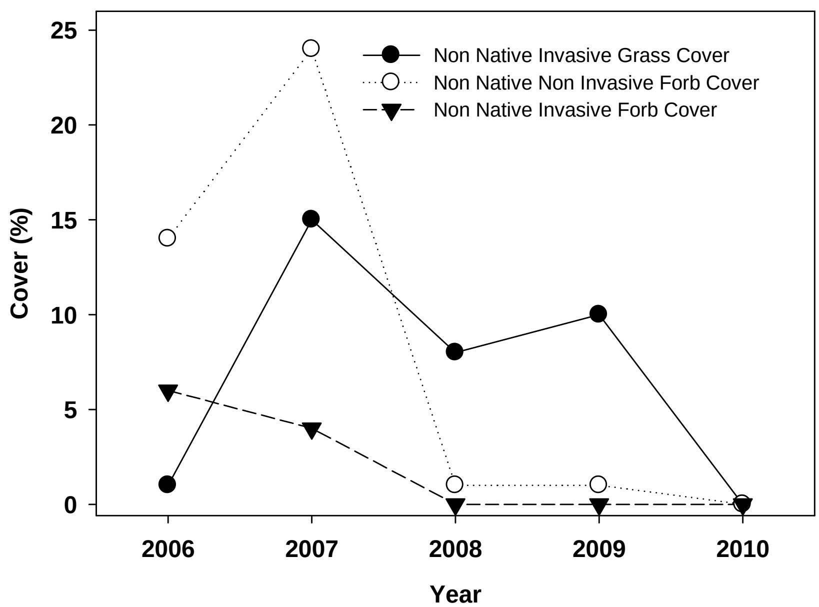

Fig.9. Percent cover of non-native grass and forb and species in BLR_002 (salvaged topsoil treatment).

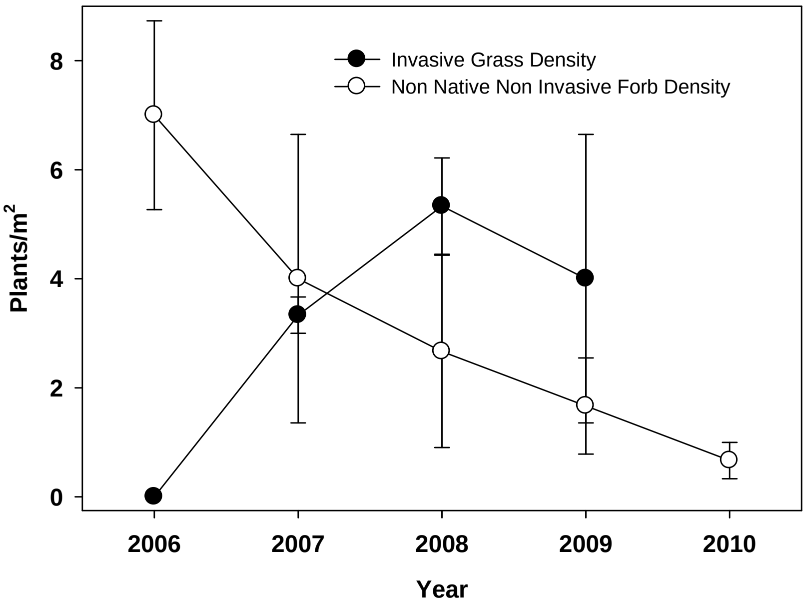

Fig.10. Density of non-native grass and forb species in BLR_002 (salvaged topsoil treatment). (mean ± 1 standard error of the mean of the mean)

Cover of native species increased 60% from 2006 to 2009 and decreased 33% in 2010. This decrease was correlated with a large drop in native *Carex* species cover (Fig. 11). Invasive species cover, predominantly comprised of *Bromus tectorum*, has averaged 8% from 2008 to 2010. Invasive species cover reached a high of 38% in 2007, with *Acetosella vulgaris* being the predominant invasive species that year. Non-invasive species cover decreased from 1% in 2009 (a single *Taraxicum officianale* plant) to zero in 2010 (Fig. 11). Bare ground cover in 2010 was 10%.

Native species densities followed a pattern similar to that of percent cover, increasing nearly nine-fold from 2006 to 2009 and then decreasing in 2010. In accordance with the data collection protocol, no grass density data were collected in 2010, which reduced the total native species density value (Fig. 12). Invasive species densities slowly declined to zero by 2010.

Native grass, forb and shrub species have established in this restoration area, and have been gradually increasing in cover and density. This plot also has fairly high invasive species cover; possibly resulting from banked seed in the salvaged topsoil. The data in this plot are highly variable from year to year and also between quadrats in the same year. The plot's close proximity to the roadside may contribute to this high variability due to excessive snow cover from plowed snow and effects of gravel and salt deposition from winter weather cleanup.

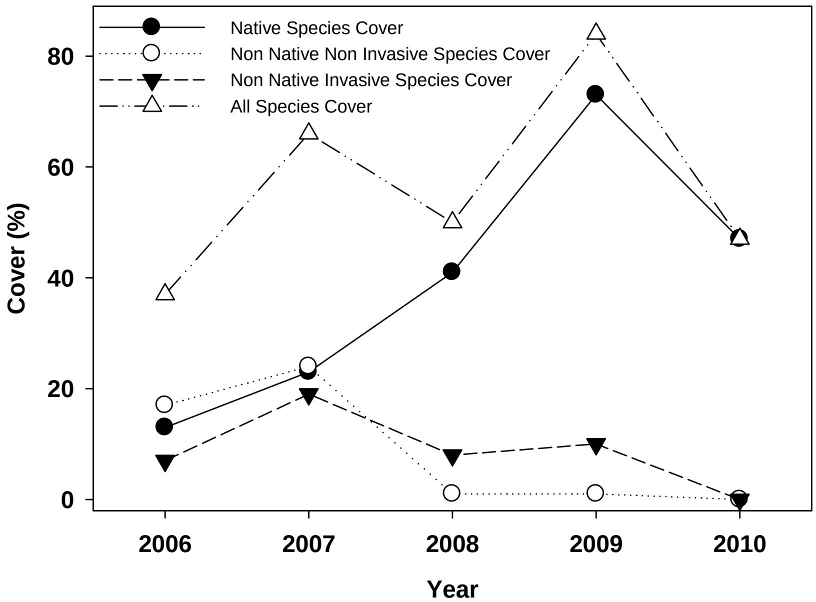

Fig.11. Native, non-native and total species percent cover in BLR_002 (salvaged topsoil treatment).

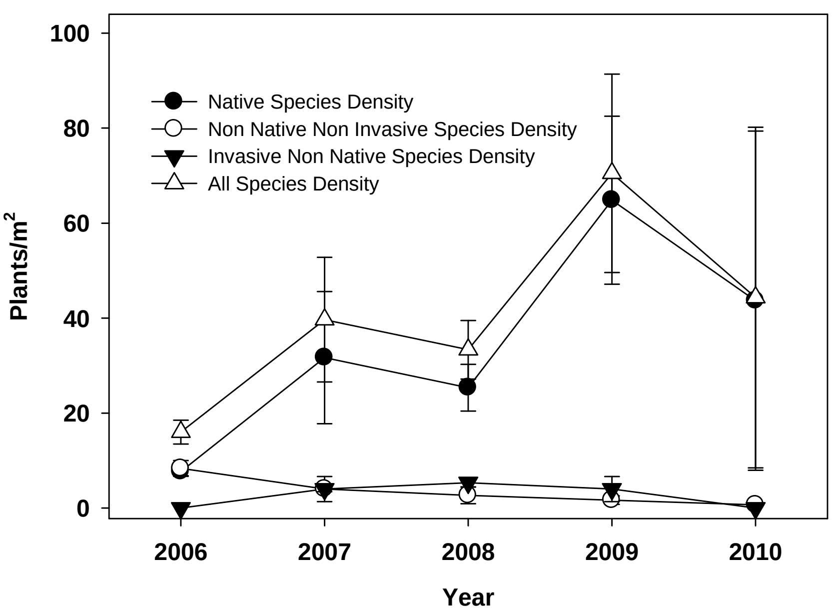

Fig.12. Density of all native, non-native, invasive and total species in BLR_002 (salvaged topsoil treatment) (mean ± 1 standard error of the mean of the mean).

BLR_003

From 2006 to 2010 native grass cover increased 10%, native forb cover increased 22%, native shrub cover increased 3% and native tree cover increased 2% (Fig. 13). The large decrease from 2009 to 2010 in forb cover is largely due to a drop in *Achillea lanulosa* cover. Native forb density increased to an average of 137 plants/m^2 in 2008 through 2010 (Fig. 14). Native grass densities from 2006 to 2009 were fairly stable and averaged 6.5 plants/m^2. Species richness of native grasses increased to nine in 2010, which was greater than in previous years.

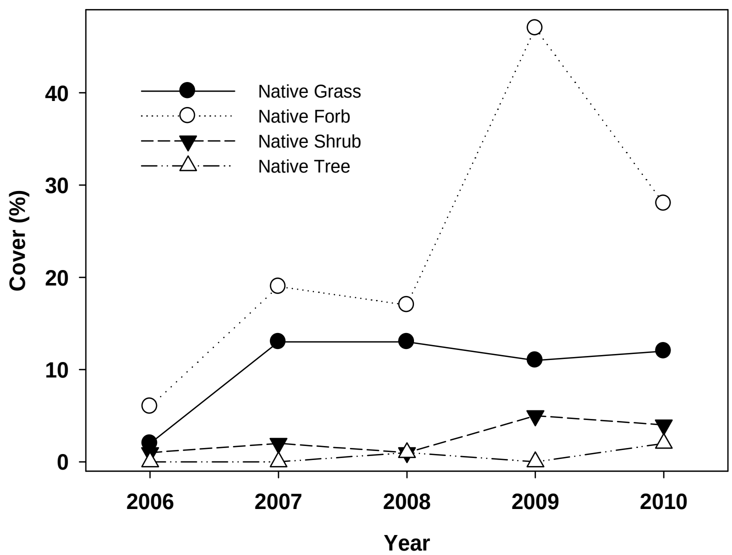

Fig.13. Percent cover of native grass, forb, shrub and tree species in BLR_003 (greenhouse and salvage planting treatment).

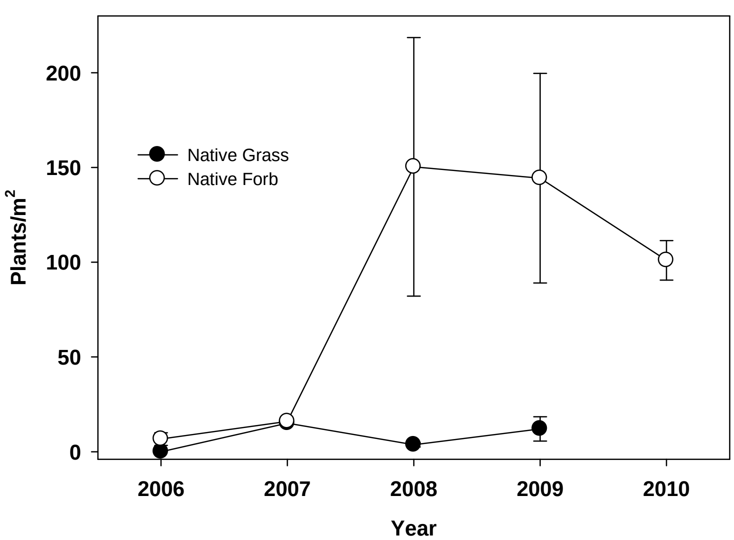

Fig.14. Density of native grass and forb species in BLR_003 (greenhouse and salvage planting treatment). (mean ± 1 standard error of the mean of the mean)

Non-native invasive grass cover remained low throughout the study, with a spike in cover in 2009 (Fig 15.) The predominant invasive grass species for all years was *Bromus tectorum*. Non-native invasive forb cover increased by 8%, with the predominant species being *Melilotus officianalis*. Non-invasive forb cover decreased to zero in 2010 with the predominant species in previous years being *Taraxicum officianale*. Average densities for all non-native species remained low, with an increase in invasive forb density in 2008 due to an increase of an unspecified *Polygonum* species listed as an exotic (Fig. 16).

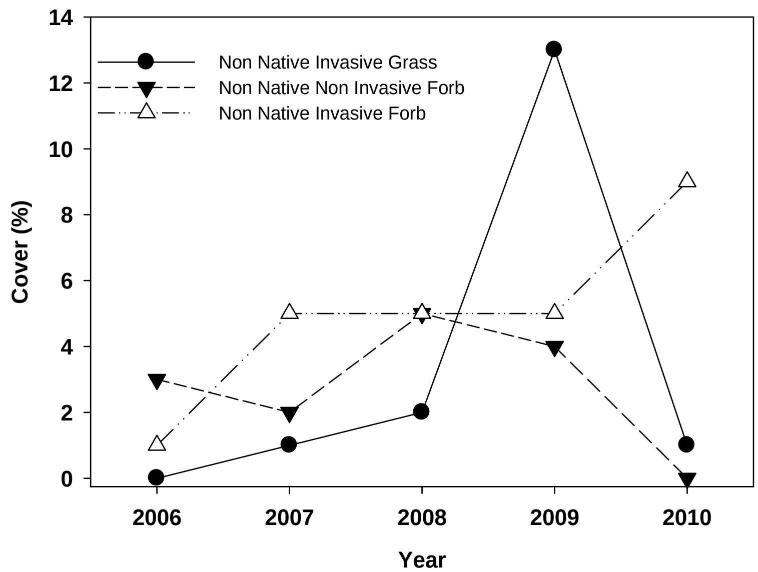

Fig.15. Percent cover of non-native grass and forb species in BLR_003 (greenhouse and salvage planting treatment).

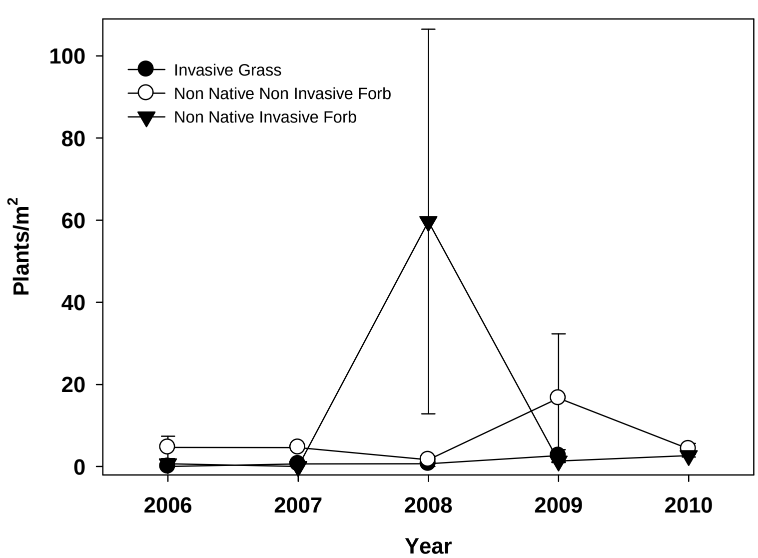

Fig.16. Density of non-native grass and forb species in BLR_003 (greenhouse and salvage planting treatment). (mean ± 1 standard error of the mean of the mean)

Native species cover increased 37% over five years, and relative native species cover increased 17% in the same time period (Fig. 17). Invasive species cover increased 9% in both percent and relative percent cover. Native species densities increased from 2006 to 2008 and averaged 138 plants/m^2 from 2008 to 2010 (Fig. 18). Bare ground cover in 2010 was 25%. Average densities for all non-native species remained low, with an increase in invasive species densities in 2008 to 2009 due to increases in *Polygonum* spp. and *Acetosella vulgaris* frequency (Fig. 18).

Native grass and forb species are increasingly becoming established in this site, with forblike species having greater density and percent and relative cover for all years. Several shrub and tree species have also become established within the plot, with *Pinus contorta, Ribes cereum and Rosa woodsii* being the most common species. Non-native invasive species presence is also increasing in this site, with *Bromus tectorum* and *Melilotus officianalis* being the most common. *M. officianalis* was especially conspicuous at this site, at points making it difficult to extend the meter tape in a straight line.

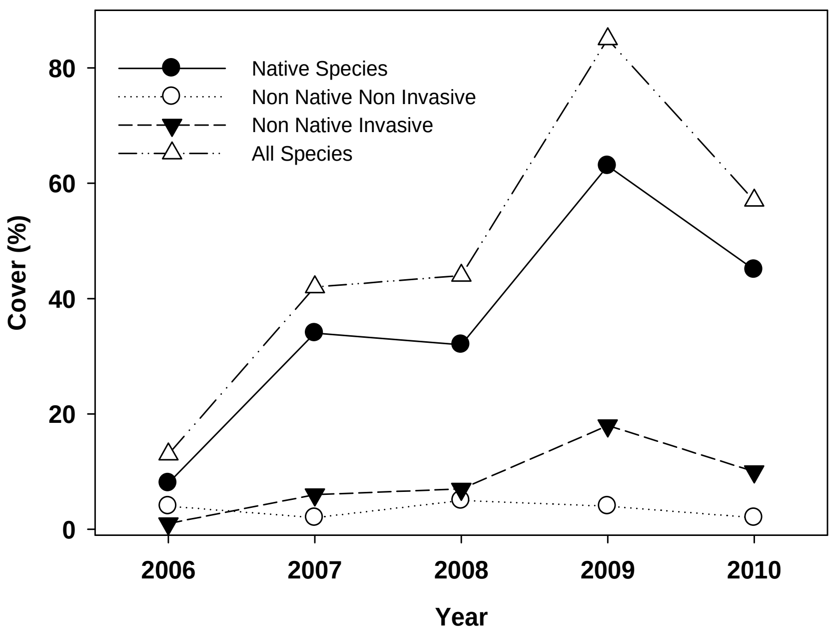

Fig.17. Native, non-native and total species percent cover in BLR_003 (greenhouse and salvage planting treatment).

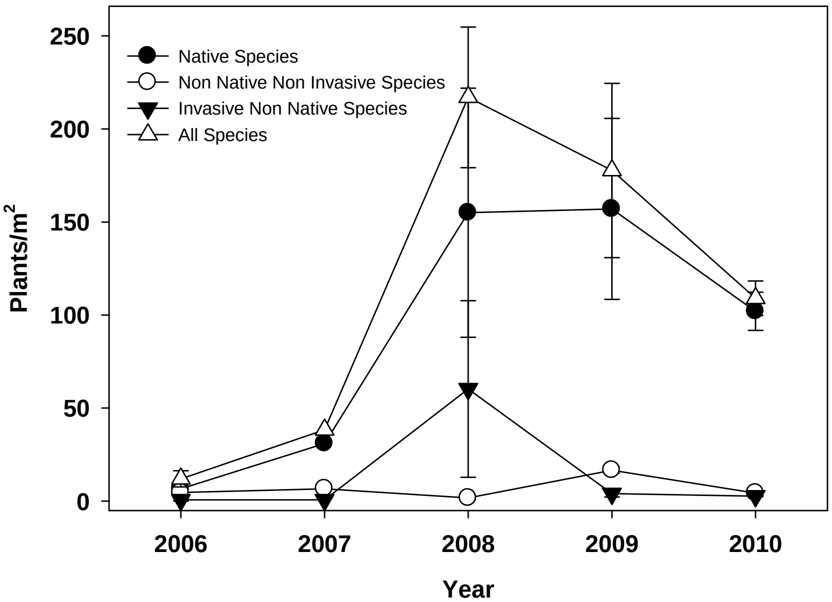

Fig.18. Total native, non-native, invasive and total species densities in BLR_003 (greenhouse and salvage planting treatment). (mean ± 1 standard error of the mean of the mean)

Success of Planted Species
In 2006, 19% of the species planted in the Glacier Gorge restoration area of Bear Lake Road Phase I were observed growing in either line-point intercept or square meter monitoring plot data. By 2010 46% of the species planted were observed growing in the monitoring plot. The only species present in the plot during all five years of monitoring was *Achillea lanulosa*. *A. lanulosa.* had an average percent cover of 6% and an average relative cover of 14% for five years. *Solidago missourensis* was observed for four years with 1.8% and 2.3% total and relative cover, respectively. *Ribes cereum* and *Pinus contorta* were both observed for three years, though in very low frequencies. *Muhlenbergia montana* was also present in the monitoring plot for three years, with a relative cover of 8.8% in 2010. See Appendix 4 for table of all planted species data.

Conclusion

Revegetation of BLR_001 has been successful, with an increase in native vegetation ground cover and plot density over the course of the study. Grasses and forbs had similar levels of success at this site. While exotic species exhibited varying cover and density values, the overall trends were decreases in non-invasive and invasive species. Of all species included in the hydroseeding mix applied to this site, *Achillea lanulosa* was the most established, with comparatively high cover and density among the other seeded species.

Cover of native vegetation has increased in BLR_002, with grass species increasing in cover and density more rapidly than forb species. Several shrub species have become established at this site as well. Exotic species cover and densities were also highly variable at this site, with an overall decreasing trend in non-invasive and invasive species cover. Density of invasive grasses has not decreased at this site, with the highly invasive grass *Bromus tectorum* being the most common species present.

Revegetation of BLR_003 has been successful, with an increase in native vegetation ground cover and plot density over the course of the study. Native forb cover has increased at a faster pace and been maintained at a higher percentage than grass cover at this site, with cover of native shrubs and trees slowly increasing as well. Overall cover and densities of exotic species was fairly low at this site, but appears to be increasing for invasive species, particularly *Bromus tectorum* and *Melilotus officianalis*. Of all planted species, *Achillea lanulosa* and *Muhlenbergia montana* were the most successful.

Literature Cited

Weber, W.A and R.C. Wittmann. 2001. Colorado Flora Eastern Slope 3rd ed. Boulder (CO). University Press of Colorado.

ACKNOWLEDGEMENTS

The authors would like to thank several people who have helped make this season a successful one:

The entire RMNP resource management team for the establishment of the monitoring program itself as well as their copious time spent training the monitoring crew and helping with data collection in the field.

Nancy Hastings at the Center for Environmental Management of Military Lands for help in indentifying particularly mysterious plant specimens.

Volunteers Claudia Striijek and Denise Brady for donating their time and knowledge to the monitoring crew and the park.

APPENDIX 1

PROTOCOL AND CHECK-OFF LIST FOR REVISITING VEGETATION PLOTSTREATMENTS AND DATA COLLECTION

REVISED JUNE 2006

1. ______APPLY TREATMENT TO PLOT

- **Record all treatments at site on Plot Treatment Record Data Sheet (in plot folder)**

<u>FIELD DATA COLLECTION</u>

2. ______MEASURE VEGETATION TRANSECT DATA

(These measurements are taken to determine the species cover)

- Use **VEGETATION TRANSECT DATA SHEET**
- **First find the two endpoints of the 15 or 30 meter transect line** (0 meter endpoint, 30 meter endpoint)**.** This may require the use of the GPS to find the "0 endpoint", and then a compass to check the azimuth to find the "30 meter endpoint" (I'm assuming that the azimuth is off of magnetic north, not true north). The Plot Location Data Sheet has this information. You may also need to use the pictures from the plot folder to help figure out where the ends are, and which end is 0 versus 30.
- **Stretch meter tape between two points, with the zero of the tape at the "0 meter endpoint".**
- **To 'read' the plot:** Begin at 30 cm from the 0 endpoint and drop a rigid pole (approx ¼ inch in diameter) to the ground. At the point where the pole intercepts the ground, record the plant species that touch the pole. There may be more than one species that touches the pole (i.e. multiple 'hits') due to different canopy layers – do not record more than one species from each canopy layer. Record genus and species whenever possible. If a plant is unknown, write "Unknown Forb #1", etc. When the pole does not intercept any vegetation at a point, record the substrate that it hits (bare soil, rock, forest litter, etc). Continue sampling every 30 cm along the transect line. The 30 meter transect will thus have 100 points of data collected. Several plots may have shorter lines (i.e. 15 meters) to measure and so will instead have 50 points.

3. ______MEASURE SQUARE METER PLOTS

(These measurements are conducted to determine plant density)

- Use **SQUARE METER PLOT DATA SHEET**
- **A total of 3 square meter frames will be read.** The directions below are for measuring 3 frames along a 30 meter tape. If you are measuring a site with a smaller transect line than 30 meters, refer to the previous year's data sheets to see what points the frames were placed at previously.
- **The first square meter frame should be read at 10 meters.** Place the square meter frame between the 9 and 10 meter marks on the tape. The frame should be placed on the **right side** of the transect when looking down the line from the 0 meter end to the 30 meter end. Then, count the number of forbs of each species located within the square meter and record this information on the data sheet. ***Grass species should be recorded as to their presence, but they do not need to be individually counted.***
- **The second and third square meter frames should be read at 20 meters, and at 30 meters, consecutively.** (Place frame on right hand side between 19 and 20 meters, and between 29 and 30 meters, consecutively).

PHOTO DATA COLLECTION

4. ______TAKE TWO PHOTOS ALONG THE TRANSECT LINE

(1) ONE FROM THE 0 METER END, LOOKING TOWARDS THE 30 METER END, AND, (2) ONE FROM THE 30 METER END, LOOKING TOWARDS THE 0 METER END. [SEE PREVIOUS YEARS PHOTOS FOR EXAMPLE]

- **Fill out photo sheets ("Origin to 30 meters", and "30 meters to Origin") in legible, dark lettering.** See previous photos in plot folders for examples. Then place photo sheets at appropriate end, and take photos. Check photos after taking them to make sure you can read the photo sheets

OFFICEWORK DATA PROCESSING

5. ______**DATASHEETS:** TOTAL THE NUMBER OF NATIVES, EXOTICS, ETC AND DO CALCULATIONS EITHER ON PLOT SHEETS OR IN EXCEL SPREADSHEET FOR EACH SITE. DO ANY OTHER ANALYSES WANTED.

6. ______DOWNLOAD, RENAME AND FILE DIGITAL PHOTOS FOR SITES IN INDIVIDUAL COMPUTER FILE FOLDERS (FOLDERS ALREADY EXIST)

7. ______PRINT OUT DIGITAL PHOTOS FOR SITES AND PLACE IN EACH SITE FOLDER

EQUIPMENT NEEDED FOR FIELD AND PHOTO DATA COLLECTION

1. 30 METER OR LONGER TAPE
2. SQUARE METER FRAME
3. 2 METER SAMPLING POLE
4. PLOT FOLDER
5. Vegetation Field Data Sheets including: SQUARE METER PLOT DATA SHEET and VEGETATION TRANSECT DATA SHEET
6. 0 AND 30 METER PHOTO SHEETS
7. DIGITAL CAMERA
8. CAMERA PHOTO CARDS
9. BLACK MARKER FOR WRITING ON PHOTO SHEETS
10. PENS/PENCILS
11. 2 CLIPBOARDS (one for each group)
12. GPS UNIT
13. COMPASS
14. PLANT ID BOOKS
15. HAND LENS AND RULER
16. EXTRA CAMERA BATTERIES
17. EXTRA REBAR AND WOOD STAKES (AND A MALLET) FOR POORLY MARKED PLOTS

IMPORTANT NOTES:

- September is a good month to read plots in since most of the plants can be recognized by this point.
- Also, when doing the vegetation data collection, it goes the fastest with four people - two teams of two. One team collecting the VEGETATION TRANSECT data (one person recording and one walking the line) and the other team collecting the SQUARE METER PLOT data (both people can count, and then record).
- **In theory**, at each plot, there should be 1 wooden stake, and 2 pieces of rebar to help find the plots. However, over time, some of these markers may have disappeared, although we tried to reinstall the markers whenever we could. Assuming the markers ARE there at the site, the wooden stake marks the 0 point of each transect line. The wooden stake should be relatively easy to see, and should be higher above the ground than the rebar. The rebar pieces mark the beginning and end of each transect. The rebar will only be sticking up about an inch above the ground. Don't ask….

APPENDIX 2

How to Do Plot Data Calculations

Initially prepared by: Julie Knudson, Oct 2003. Updated Aug 2004. Updated Oct 2006, Scott Esser

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Basic 3 equations:

Data Analysis:

1 **Actual Percent Cover** is the number of points at which a species occurs on a transect divided by the total number of transect points, multiplied by 100.

$$\text{Percent cover}_{sp} = \frac{\text{hits}_{sp} \times 100}{\text{Points}}$$

Percent cover $_{sp}$ = percent cover of a transect species
Sp = index for species
hits $_{sp}$ = number of points on which a species occurs
points = total number of points on a transect

2 **Relative Percent Cover** is the percent cover of a species divided by the sum of the percent cover of all species, multiplied by 100. Relative cover is only calculated for live plants. Therefore, the sum of percent cover ignores dead plants and non-plant materials such as soil, logs, etc. The total of all relative cover calculations is always equal to approximately 100%.

$$\text{Relative cover}_{sp} = \frac{\text{percent cover}_{sp} \times 100}{\text{percent cover}_{total}}$$

3 **Density per hectare** is the number of individuals per hectare and can be calculated using the following calculation:

$$\text{Density}_{sp} = \frac{\text{count}_{sp} \times \text{ha}}{\text{area}}$$

1 hectare = 10,000 m^2

Before performing the calculations, please read the following to make sure you understand the procedure. Data calculations prior to end of season 2003 were performed incorrectly, and it could easily happen again if the basic principles of the calculations are misunderstood. Fall 2003 data calculations are correct. The following explains the correct methodology.

OUTLINE

I. Data Calculation Methodology for: VEGETATION TRANSECTS

Calculation Revision: Data calculations prior to Fall 2003 used the number of "total hits" (instead of "total points") to divide by to get "Percent cover" of each species individually. We are now using "total points" as the divisor to get "Percent Cover" of each species (see attached sheets "Calculation Examples"). This change has been made for several reasons:

(1) The equations outlined in the "Fire Effects" Manual require the use of "total points", not "total hits", as a divisor to obtain "Percent Cover" of each species, and it was decided previously that the "Fire Effects" Manual would serve as the official guideline for Exotics calculations

(2) Dividing by "points" instead of "hits" is a better method because: At each "point" along the 100 or 50 meter vegetation transect, there can be multiple "hits". For example, there could be both smooth brome and Canada thistle that are "hits" at one point. So, when summing the total number of "hits" for a 100 meter transect (which would have 100 "points"), it is possible to have a total number of "hits" greater than 100. However, at any given "point", it is only possible to "hit" a single species once (i.e. Canada thistle would not be "hit" twice at a single point). As a result, when determining the "Percent Cover" of an individual species, say Canada thistle, one would want to divide the number of "hits" of that species along the vegetation transect by the total number of "points" possible where the species could have been "hit". This would be 100 "points" along a 100 meter transect.

If you determined "Percent Cover" of an individual species by dividing the number of "hits" of the species by the total number of "hits" for all plants along the transect line (say the number of "hits" for Canada thistle was 40, out of a total number of plant "hits" of 105 along a 100 meter transect), you are stating that out of 105 possibilities, Canada thistle was "hit" 40 times. This would not be correct.

*"Points" are the number of locations along a vegetation transect (100 or 50 meter) that underlying vegetation is characterized. "Hits" are determined by dropping a straight pointer down at each "point" along the vegetation transect. Each species that is encountered at a particular point is considered to be a "hit". Rocks and non-vegetation elements are also counted as "hits".

This change to the method of calculation of "Percent Cover" of an individual species for the VEGETATION TRANSECT DATA is the only calculation change that was made to the previous years calculations. However, since there are other calculations made based on the results of the "Percent Cover" calculation, it was necessary to recalculate all of the Vegetation Transect data from previous years. The previous and current years data were calculated and the results are presented in the Excel file "Exotics_calcs_2003.doc".

Notes on Actual Percent Cover of a species versus Relative Percent Cover of a species:

- For some reason, the Fire Manual refers to Actual Percent Cover as "*Percent Cover*", and the Relative Percent Cover as "*Relative Cover*". This is confusing, so for our calculations we have used the terms Actual Percent Cover and Relative Percent Cover. I have included the Fire Manual's terms in parentheses in case there is any question below.
- The Actual Percent Cover (*Percent Cover*) of a species is the actual percent of the total plot area that is covered by that particular species. The Relative Percent Cover (*Relative Cover*) of a species is the percent of cover of that particular species, relative to the cover of all of the other species combined.
- Total Actual Percent Cover (*Total Percent Cover*) can be over 100%. Total Actual Percent Cover (*Total Percent Cover*) is calculated by summing the percent covers of each individual species. Since technically there can be more than one "hit" at a point, it means that technically two different species populations may overlap each other, hence the potential to have a Total Actual Percent Cover (*Total Percent Cover*) over 100%.
- Total Relative Percent Cover (*Total Relative Cover*) should not be over 100%. Total Relative Percent Cover (*Total Relative Cover*) would be calculated by summing the relative covers of each individual species, but this value was not needed for our calculations.

Explanation of Excel spreadsheet for Exotics Calculations

- Data entry should be self-explanatory. The yellow columns represent the data entry cells. All of the calculation formulas can be observed by clicking on the appropriate cell. The calculations used are those directly from the Fire Effects Manual. All of the exotic species were entered using a two letter code. The full name of the species can be observed by clicking on the red "comment" triangle in the upper right hand corner of the cells.
- Care should be taken if copying and pasting formulas for further calculations. In particular, note that all of the formulas in the "% Relative Cover" columns should refer back ONLY TO THE TOP CELL of the prior "Total % Cover" column. This should definitely be checked after copying/pasting!

- Also note for future reference that the Final Summary Calculations (in purple) were altered to accommodate those plots that differed from the norm – i.e. where "Post-Year1" information was not yet available. For example, ordinarily the Final Summary Calculations summarize the change in Actual Percent Cover, Relative Percent Cover, and Density between the "Pre-Treat" values and the "Post-Year1" values (Post-Year1 minus Pre-Treat). Where "Post-Year1" values are not available yet, the calculated changes in Actual Percent Cover, Relative Percent Cover, and Density are a result of the subtracted difference of "Pre-Treat" and "Post-Treat" values. So, if additional data is added, these formulas must be revised to accommodate the new data! Note also that the labeling of the columns were altered slightly to accommodate these differences, so take care if copying/pasting for new sites.
- Since the calculation of Relative Percent Cover requires the calculation of Total Percent Cover, all of the native species were lumped into one category referred to as "Natives", versus calculating out all of the individual percent covers of each native species, which was not of interest for the current data summary.

APPENDIX 3

Percent cover and density of hydroseeded species in BLR_001 restoration monitoring site.

BLR_001	Percent Cover				
HYDROSEEDED SPECIES	**2006**	**2007**	**2008**	**2009**	**2010**
Achillea lanulosa	1		2	3	6
Amerosedum lanceolatum					
Antennaria spp.				2	
Castilleja spp.					
Chondrosum gracile					
Elymus elymoides					
Erigeron spp.	1				
Eriogonum umbellatum					
Hesperostipa comata					1
Heterotheca villosa				2	2
Koeleria macrantha		3			
Lupinus spp.					
Macaranthera pattersonii		1			
Muhlenbergia montana					
Penstemon spp.			1		
Phacelia spp.	1				
Solidago spp.					
Stipa robusta					

BLR_001	Density (plants/m^2)				
HYDROSEEDED SPECIES	**2006**	**2007**	**2008**	**2009**	**2010**
Achillea lanulosa		1	1	2.67	5.67
Amerosedum lanceolatum					
Antennaria spp.					
Castilleja spp.					
Chondrosum gracile					
Elymus elymoides					
Erigeron spp.					
Eriogonum umbellatum					
Hesperostipa comata					
Heterotheca villosa					0.33
Koeleria macrantha		1			
Lupinus spp.					
Macaranthera pattersonii					
Muhlenbergia montana					
Penstemon spp.					
Phacelia spp.					
Solidago spp.					
Stipa robusta					

APPENDIX 4

Percent cover relative cover and density of planted species in BLR_003 restoration monitoring site.

Planted Species Percent Cover BLR_003

	Percent Cover				
Planted Forbs/Grass/Carex	**2006**	**2007**	**2008**	**2009**	**2010**
Achillea lanulosa	3	5	5	14	3
Antennaria sp.		1		1	2
Artemisia ludoviciana	2				
Aster porteri			1		1
Carex stenophylla ssp. eleocharis					2
Chondrosum gracile					
Drymocallis fissa					1
Fragaria virginiana ssp. Glauca					
Heterotheca villosa				1	
Koeleria cristata					
Muhlenbergia montana	1			2	5
Oxytropis sp.					
Potentilla pensylvanica					
Potentilla sp.					
Solidago missouriensis	1	1		3	2
Thermopsis divaricarpa			2		
Planted Shrubs					
Juniperus communis					
Ribes cereum		2		2	1
Rosa woodsii				1	
Planted Trees					
Acer glabrum					
Alnus incana					
Pinus contorta			1		2
Pinus flexilis					
Populus tremuloides					

Planted Species Relative Cover BLR_003

	Relative Cover				
Planted Forbs/Grass/Carex	**2006**	**2007**	**2008**	**2009**	**2010**
Achillea lanulosa	23.1	11.9	11.4	16.5	5.3
Antennaria sp.		2.4		1.2	3.5
Artemisia ludoviciana	15.4				
Aster porteri			2.3		1.8
Carex stenophylla ssp. eleocharis					3.5
Chondrosum gracile					
Drymocallis fissa					1.8
Fragaria virginiana ssp. Glauca					
Heterotheca villosa				1.2	
Koeleria cristata					
Muhlenbergia montana	7.7			2.4	8.8
Oxytropis sp.					
Potentilla pensylvanica					
Potentilla sp.					
Solidago missouriensis	7.7	2.4		3.5	3.5
Thermopsis divaricarpa			4.6		
Planted Shrubs					
Juniperus communis					
Ribes cereum		4.8		2.4	1.8
Rosa woodsii				1.2	
Planted Trees					
Acer glabrum					
Alnus incana					
Pinus contorta			2.3		3.5
Pinus flexilis					
Populus tremuloides					

Planted Species Density BLR_003

	Density (plants/m^2)				
Planted Forbs/Grass/Carex	**2006**	**2007**	**2008**	**2009**	**2010**
Achillea lanulosa	1.30		29.70	42.00	37.33
Antennaria sp.	0.33		5.00	0.33	0.67
Artemisia ludoviciana				1.00	3.33
Aster porteri			2.33		0.67
Carex stenophylla ssp. eleocharis					
Chondrosum gracile					
Drymocallis fissa				0.33	2.33
Fragaria virginiana ssp. Glauca				0.33	0.33
Heterotheca villosa				1.00	
Koeleria cristata					
Muhlenbergia montana					
Oxytropis sp.		0.33			
Potentilla pensylvanica				1.67	
Potentilla sp.			1.67		
Solidago missouriensis					
Thermopsis divaricarpa					
Planted Shrubs					
Juniperus communis					
Ribes cereum					
Rosa woodsii					0.67
Planted Trees					
Acer glabrum					
Alnus incana					
Pinus contorta				0.67	0.33
Pinus flexilis					
Populus tremuloides					