Measuring Early Vegetation Changes after Fire in Mountain Big Sagebrush (*Artemisia Tridentata* Nutt. *ssp.* s*aseyana* [Rydb] Beetle) Rangelands

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ABSTRACT
In rangeland fire research, before fire vegetation conditions have rarely been measured, although this information is necessary for predictions of after fire vegetation recovery. Multiple prescribed fires were lit 2002 and 2003 at the USDA-ARS United States Sheep Experiment Station in a mountain big sagebrush (*Artemisia tridentata* Nutt. ssp. *vaseyana* [Rydb] Beetle) steppe ecosystem that was relatively free of exotic plants. Measurements of cover components and plant species frequencies were taken before and for several years after the fires. Cover of forbs, grasses and bare ground returned to before fire levels after two yr. Shrub cover declined from 36 to 6%. Fire reduced the frequencies of three species (*A. tridentata* ssp. *vaseyana*, *Festuca Idahoensis*, and *Cordylanthus ramosus*). The fire also increased the frequencies of four species (Hesperostipa comata, Polygonum douglasii, Chenopodium fremontii and Chenopodium leptophyllum), but only P. douglasii increase was for more than a year. This study demonstrates that in a mountain big sagebrush steppe ecosystem, without significant non-native species or anthropogenic disturbances, cover components and plant species frequencies are only minimally altered and the plant community that develops after fire is similar to the one before fire and will most likely result in a return to a sagebrush dominated community.

Keywords: rangelands, vegetation, measurement, fire

INTRODUCTION

Wildfire is a natural part of the sagebrush steppe ecosystem (Blaisdell et al. 1982) with fire-free intervals before European settlement varying from 20 to 25 yr in higher elevation *Artemisia tridentata* ssp. v*aseyana* (Burkhardt and Tisdale 1976). In a Clementsian model developed in west-central Utah (Barney and Frischknecht 1974), fire in the sagebrush steppe restarts plant succession, which begins with an annual weedy stage that is followed by a perennial grass/forb stage 3 or 4 yr after a fire. Following stages of succession include dense sagebrush potentially followed by climax juniper woodland. Dense sagebrush stands are associated with declines in plant diversity and increased fire risk (Johnson et al. 1996). Additionally, dense sagebrush stands typically have decreased forage production of perennial grasses and forbs (Harniss and Murray 1973; Bork et al. 1998). We hypothesize that, as sagebrush stands increase in age, the succession of plants after fire will be altered.

Recent research has measured altered succession after fire due to the influence of exotic, invasive weeds resulting in increased fire frequency (Pellant 1990; Whisenant 1990). This and other observed alterations have resulted in the development of state and transition models of plant succession (reviewed by Stringham et al. 2003). To predict plant succession after fire, it is important to know the state of the vegetation before the fire. Most research conducted on vegetation recovery after fire has been initiated after the fire with little or no information on before fire vegetation (Harniss and Murray 1973; Barney and Frischknecht 1974; Wambolt et al. 2001; Wrobleski and Kauffman 2003). To properly test state and transition models, knowledge of vegetation conditions before disturbance is critical.

There are few areas of sagebrush steppe in Eastern Idaho are relatively free of exotic plants and available for prescribed fires. At the USDA-ARS United States Sheep Experiment Station (USSES) two areas that have only been lightly grazed by sheep and have a very low density of exotic plants (small patches of *Verbascum thapsus* on rock outcrops and trace amounts of *Taraxacum officinale*) were selected to measure influence of before fire vegetation on plant recovery after fire.

The objectives of this study were to determine vegetation change after fire in an ecosystem relatively free of exotic plants and to determine whether time since last fire influenced after fire vegetation. The results of this study will provide a baseline for subsequent prescribed fires in areas of the sagebrush steppe with vegetation communities that have larger invasive plant components.

METHODS

In the summer of 2001, an area in the Northeast corner of the USSES spring-fall range (lat 44º14'44" N, long 112º12'47" W) with a 34 to 42% shrub cover was selected for a prescribed burn (Figure 1). The site, at an elevation of 1,800 m, is in the northeastern part of the sagebrush steppe region (West 1983). Soils are fine-loamy, mixed, frigid Calcic Argixerolls derived from wind-blown loess, residuum, or alluvium on slopes ranging from 0 to 12% (Natural Resources Conservation Service 1995). Climate is semiarid with cold winters, several months have mean temperatures below freezing, and warm summers with daily highs averaging 27 C. During the study precipitation amounts were below the long term average from 2001 to 2003 (Table 1). Annual precipitation averages 330 mm, with up to 60% falling in the winter as snow. Mountain big sagebrush (*Artemisia tridentata* ssp. v*aseyana*), antelope bitterbrush (*Purshia tridentata*), Montana wheatgrass (*Elymus albicans*), Idaho fescue (*Festuca idahoensis*), Sandberg bluegrass (*Poa secunda*), rosy pussytoes (*Antennaria rosea*), longleaf fleabane (*Erigeron corymbosus*), and common yarrow (*Achillea millefolium*), dominate the vegetation.

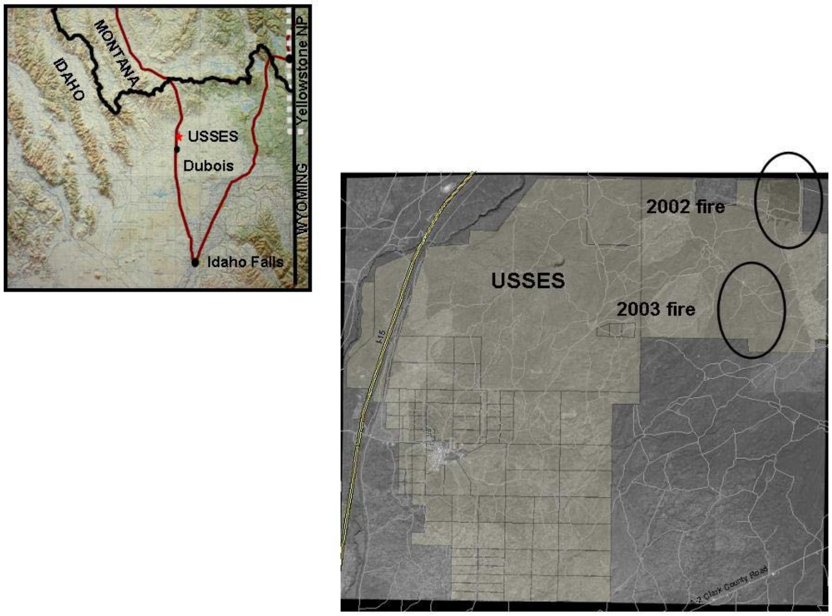

Figure 1. The U.S. Sheep Experiment Station is located in Eastern Idaho in the Upper Snake River Plain.

Table 1. Precipitation at the U.S. Sheep Experiment Station during the study and the 30 yr average

Month	2001	2002	2003	2004	2005	30-yr avg
				cm		
January	1.35	1.70	0.74	1.93	1.91	1.93
February	0.91	0.43	1.96	2.90	0.28	1.73
March	1.19	0.89	1.27	1.27	2.79	2.36
April	2.67	2.03	8.94	3.00	4.04	2.82
May	0.30	2.26	3.96	3.66	7.14	4.90
June	2.51	3.28	0.71	4.39	5.03	4.27
July	2.31	0.71	0.13	1.88	0.18	2.69
August	1.96	0.61	0.38	2.31	1.22	2.49
September	0.43	1.91	0.84	2.36	3.71	2.51
October	2.41	0.97	0.10	7.09	5.11	2.16
November	3.43	1.80	0.66	0.00	2.44	2.74
December	3.68	2.24	3.89	3.00	5.31	2.36
Total	23.16	18.82	23.57	33.78	39.14	32.97

The fires (2002 and 2003) were located on land (260 ha) that was typically sheep grazed for the last 20 yr. Sheep grazing usually occurred for 1 wk each spring and fall with an average yearly stocking density of 40 sheep d ha^{-1}. The land was not grazed the year before each fire. The southern two thirds of the 2002 site and the entire 2003 site burned in 1981 whereas the northern third of the 2003 site last burned in 1960. In June of the burn yr, two fire lines were constructed using a road grader. One encompassed a 250 ha area and the other fire line isolated approximately 100 ha within the larger area. The interior areas were burned in September using standard prescribed fire techniques for the sagebrush steppe. Initially, the graded fire lines on the north and east sides were widened using successive strips of fire (1, 3, 10, 20 m) from the graded fire line, creating a 20 m wide black line. Then, starting on the northwest and southeast corners, lines of fire were ignited approximately 20 m east or north of the interior fire line towards the southwest corner. The black line was started when fire conditions were adequate for fire spread (typically around 10 am). In both years, the first and largest prescribed fire was completed at 4:30 pm. In 2002, 10 additional fires were ignited in the area south and east of the first fire. In 2003, three additional fires were ignited in an area north and east of the first fire (Table 1). Fires less than 4 ha were ignited from a point and allowed to burn until a certain size was achieved or the fire reached interior fire line. Fire crews suppressed fires using water and trying not to enter the burned area. Fires greater than 4 ha were ignited with a specific length of fire the length that was estimated to result in a pre-determined size of fire. In the largest four fires, some areas within the boundaries of the fire were not burned. These areas were ignited during the second day. In 2002, the last fire of the second day was planned to burn 30 ha in the northwest corner of the burn area. However, decreasing temperatures and solar radiation prevented the fire from spreading throughout the desired area.

Measurements of plant frequency, ground cover and, soil movement were taken at 100 permanent plots before and after the fire in 2002 and at 25 plots in 2003. The plots were located on a GIS database map of the site using a stratified random design. In 2002, 10 plots were outside the fire line, 10 plots were in the area that would be black lined, 25 plots were in the area of the large fire, 5 plots were in the green strip between the large fire and the interior fire line, and 50 plots were in the area where the small fires were ignited. In 2003, 5 plots were located outside the intended burn area, 20 in the large burn area. After the 2003 fire, only 1 plot of the 20 was in a small fire area, the other 19 were in large fire area. In the field, GPS units were used to locate each plot. At each plot a nested frequency quadrat frame was placed in a spot that was representative of the area vegetation. Two red, 24 penny nails were used to mark opposite corners of the frame for precise measurements after the fire. Cover of shrubs, grasses, forbs, litter, bare ground, and rock were estimated visually. Soil movement was measured using a piece of rebar that was placed at a third corner of the nested frequency quadrat frame and pounded in until about 35 cm remained above ground. Height of the rebar above ground was measured to the nearest mm. Species frequency, cover estimates, and soil movement were measured in July of 2002, 2003, 2004, and 2005.

Data from each fire were analyzed separately. The data were determined to be normally distributed using a UNIVARIATE procedure on model residuals with the Shapiro-Wilk statistic (SAS Inst. Inc., Cary, NC). For the cover analysis, repeated measures analyses of variance (ANOVA) were used to examine the relationship between time since fire and percent cover of each class (forb, grass, shrub, soil, litter, and rock) in burned and unburned plots within each year. An ANOVA with paired contrasts between each set of consecutive years was used to determine changes in percent cover between years for burned and unburned plot separately (SAS Inst. Inc., Cary, NC). The same analyses were used within burned plots from the 2002 fire to determine if time before last historic fire (21 or 42 yr) impacted vegetation recovery.
In order to analyze for differences in plant species frequency in 2002, only species that were in 30% or more of all sample plots (burned and unburned plots combined) could be used (19 of 70 species) to satisfy assumptions of normality. The greatest sensitivity to change is found when plant frequencies are near 50% of the plots (Stephen Bunting, personal communication). Therefore, we selected quadrat sizes (110, 870, 2210, or 4420 cm^2) independently for each species based on frequency percentages consistently nearest 50% for all years in burned and unburned plots. Presence/absence data were tallied for the chosen quadrat size for each species. For each species, 2x2 chi-square analyses with McNemar's test (SAS Inst. Inc., Cary, NC) were used to detect differences in frequencies between pairs of consecutive years for burned and unburned plots. If species were absent from at least one yr of the paired comparisons, a statistical determination could not be made (Table 2), however, the loss of a species was noted. Differences

were considered significant when the F-test probability was ≤ 0.05. The 2003 plant species frequency analyses could not be conducted. The small number of plots (25) biased the chi-square test statistic because the minimum frequency for each cell was not at least 5 for each 2x2 chi-square analysis (Zar 1974).

Table 2. Fire sizes in the 2002 prescribed fires on the spring-fall grazing property of the U. S. Sheep Experiment Station before grazing initiated

Fire	Size	Vegetation age
	ha	——yr——
1	104	21 and 42
2	10.2	42
3	2.63	21
4	1.55	21
5	1.29	21
6	1.23	21
7	0.51	21
8	0.46	21
9	0.20	21
10	0.09	21
11	0.001	21
12	0.001	21

RESULTS

COVER COMPONENTS

There were differences in many of the cover components (grass, forb, shrub, bare ground, litter, and rock) due to fire, time, and the interaction of fire and time. Before the fire in 2002, all cover components were similar except for bare ground ($P = 0.04$) where the area to be burned averaged 13% and the area that was not burned averaged 19%. Before the fire in 2003, all cover components were similar except for forbs ($P = 0.01$) where the area to be burned averaged 16% and the area that was not burned averaged 4%. There was no soil movement over the course of the study in the burned and unburned plots.

In the 2002 fire over the course of the experiment, grass cover (Figure 2a) was greater overall in the burned area compared to the unburned ($P = 0.03$) and there was an interaction of time and burn ($P < 0.0001$). Grass cover in the burned area declined in the yr following fire and increased to before fire amounts in second and third yr after the fire. In the unburned area, grass cover did not change the first yr after fire, declined in the second yr and did not recover in the third yr. There was more grass cover in the unburned area the yr after the fire compared to the burned, but there was more grass cover in the burned area in second and third yr compared to the unburned. In the 2003 fire, grass cover did not differ between burned and unburned areas (Figure 3a). However, grass cover declined ($P=0.006$) the first year after the fire and increased ($P = 0.05$) in the second year after the fire.

The 2002 fire did not change forb cover ($P = 0.88$) over the course of the experiment (Figure 2b). However, forb cover changed with time ($P < 0.0001$) and there was an interaction with time and fire ($P = 0.0003$). In the first yr after the fire there were more forbs in the unburned area ($P = 0.03$) compared to the burned area. In first yr after the fire, forb cover declined in both burned ($P = 0.0005$) and unburned areas ($P = 0.02$). Forb cover increased ($P < 0.0001$) in the burned area in the second yr compared with the first yr after fire and forb covers decreased in burned ($P = 0.0002$) and unburned ($P = 0.003$) areas in the third yr after the fire. In the 2003 fire, forb cover the yr after the fire was similar in the burned and unburned areas, and forb cover increased (P = 0.01) in the unburned area (Figure 3b). In the second yr following fire, forb cover declined in the unburned area (P = 0.03) and was less than in the burned area (P = 0.01). Over the course of the study forb cover was greater (P = 0.01) in the burned compared to the unburned area and forb cover in the burned area did not change.

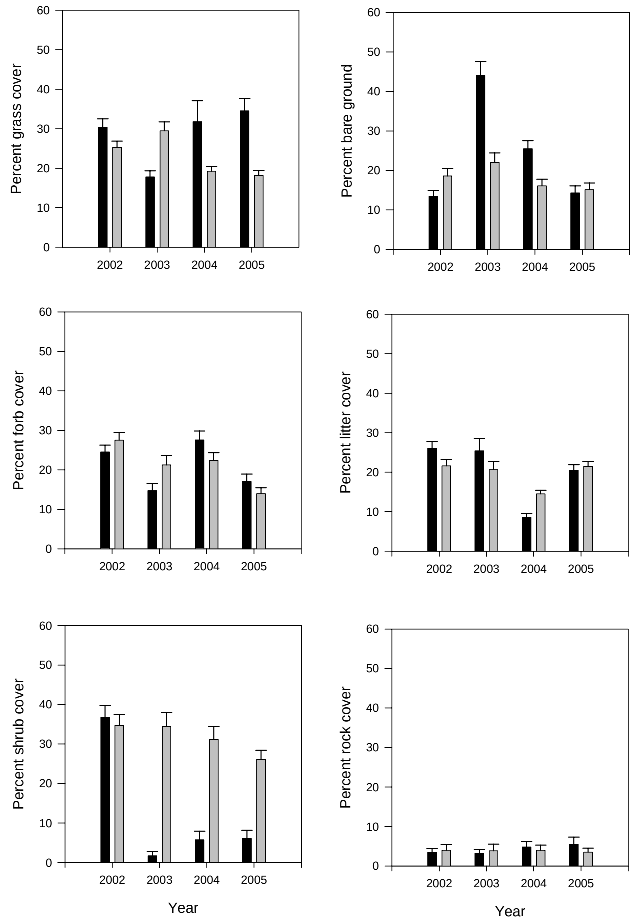

Figure 2. Cover components of burned (dark bars) and unburned (light bars) areas before and three yr after the 2002 prescribed fire at the U. S. Sheep Experiment Station.

Fire reduced (P < 0.0001) shrub cover in both the 2002 and 2003 fires (Figures 2c and 3c). The fire reduced shrub cover from 37 to 2% in the 2002 fire and 35 to 9% in the 2003 fire the yr after the burns. In the 2002 fire, each yr after the fire, shrub cover was less in the burned than unburned areas (P < 0.0001). In the 2003 fire, shrub in the burned and unburned areas was not different until the second yr after the fire (P < 0.0001). Shrub cover did not change in the unburned areas during the course of the study in both the 2002 and 2003 fires. Shrub cover in the burned area did not change after the initial decline caused by the fire for both 2002 and 2003 fires.

In the 2002 fire, bare ground differed due to burning (P = 0.007) and time (P = 0.0001), and there was an interaction (P < 0.0001) of time and burning (Figure 2d). In the year after the fire, the burned areas increased (P < 0.0001) in bare ground and there was more (P < 0.0001) bare ground in the burn area compared to the unburned area. In the burn area, bare ground decreased from 2003 to 2004 and from 2004 to 2005 (P < 0.0001 and = 0.0009, respectively). There was more (P

= 0.0004) bare ground in the burned area than the unburned area in second yr after the fire, but not in the third. In the unburned area, bare ground declined in second yr after the fire (P = 0.03) and stayed at that amount in the third yr after fire. In the 2003 fire, bare ground did not change in the unburned area over the course of the study (Figure 3d). In each yr of the study, there was no difference in bare ground between the burned and unburned areas. However, bare ground in the burned plots increased (P = 0.003) the yr after the fire and decreased (P = 0.002) to before fire levels the following yr.

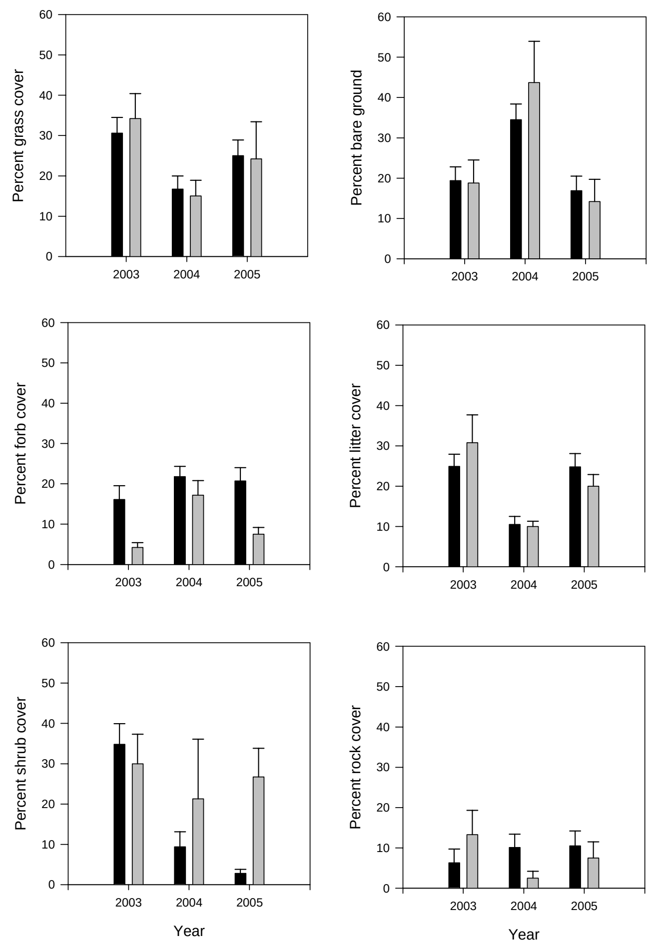

Figure 3. Cover components of burned (dark bars) and unburned (light bars) areas before and 2 yr after the 2003 prescribed fire at the U. S. Sheep Experiment Station.

Over the course of the experiment, burning did not alter (P = 0.74) litter cover (Figure 2e) in the 2002 fire. There was a time effect (P < 0.0001) and a time by burn interaction (P = 0.002). Litter did not change the yr after the fire, but in 2004 litter cover declined in both the burned (P < 0.0001) and unburned (P = 0.005) areas and increased to before fire conditions in 2005 in the burned (P < 0.0001) and unburned (P = 0.002) areas. In the second yr after the fire there was more litter in the unburned than the burned areas (P < 0.0001). In the 2003 fire, burning did not alter (P = 0.82) litter cover (Figure 3e) over the course of the experiment. There was a time effect (P < 0.0001) with litter declining the yr after the fire in both the burned (P = 0.0001) and unburned (P = 0.002) areas and increasing the second yr after the fire in the burned (P = 0.0001) and unburned (P = 0.05) areas.

Rock cover did not change over the course of the experiment in either the 2002 or 2003 fire, and there were no differences between burned or unburned areas (Figure 2f and 3f).

Time since the last historic fire (21 or 42 yr) did not appear to affect cover components after the 2002 fire. However, before the fire, bare ground was greater (P = 0.05) in the younger stand compared to the older (15.6 and 9.3%, respectively).

PLANT SPECIES FREQUENCIES

Based on the frequency plots analyzed at 870 cm^2 nested area, the two most common species were *Poa secunda* and *Elymus albicans*, both perennial grasses. Plants analyzed at 2210 cm^2 nested area were perennial grasses *Festuca idahoensis* and *Koeleria macrantha*, perennial forb *Erigeron corymbosus*, and annual forb *Polygonum douglassii*. The remaining plants were analyzed at the 4420 cm^2 area.

Of the 19 plant species analyzed for frequency, three (*Artemisia tridentata spp. vaseyana*, *Festuca idahoensis*, and *Cordylanthus ramosus*) declined and two (*Hesperostipa comata* and *Polygonum douglassii*) increased in the burned area (Figure 4a-e). Except for *Elymus albicans* (Figure 4f), the frequencies of the other plant species varied similarly during the course of the study (Figure 4g-s). *Viola nuttallii* and *Microseris nutans*, two perennial forbs, were only observed in abundance in 2004 in the burned and unburned plots and *Mertensia oblongifolia*, another perennial forb, disappeared in both the burned and unburned areas in 2005 (Figure 4g-i). Frequencies of *Poa secunda* and *Koeleria macrantha* increased over time (figure 4j-k). Frequencies of *Allium acuminatum*, a perennial forb, and *Gayophytum racemosum*, an annual forb, increased in 2004 (Figure 4l-m). The remaining plant species remained relatively stable over the course of the study (Figure 4n-s). Frequencies of analyzed and unanalyzed species at the 4420 cm^2 area are listed in Appendix A for the 2002 fire and Appendix B for the 2003 fire.

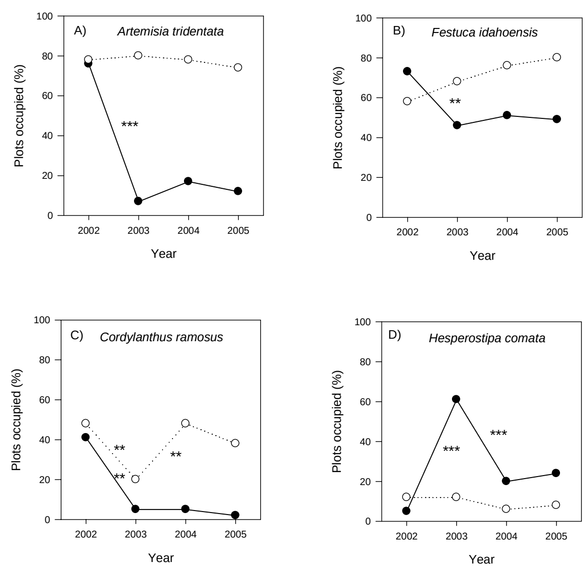

Figure 4. Plant species frequencies in burned (solid line) and unburned (dashed line) areas before and 3 yr after the 2003 prescribed fire at the U. S. Sheep Experiment Station.

DISCUSSION

Both 2002 and 2003 fires burned more than 95% of the area and removed more than 95% of the vegetation biomass in the burned areas (visual observation). The fires were classified as low severity as the surface was largely black with some isolated pockets of gray ash and, in the 2003 fire, soil temperatures remained below 50 C at 0.5 cm depth (Hungerford 1996).

COVER COMPONENTS

Although vegetation decreased initially in the yr following fire, forbs, grass, and bare ground returned to or exceeded before fire levels after 2 yr. These results are consistent with previous studies (Harniss and Murray 1973; Barney and Frischknecht 1974) that reported vegetation in the first years after a fire being dominated by grasses and forbs.
An objective of this study was to determine whether time since last fire impacted subsequent vegetation. Time since the last fire (21 or 41 yr) did not have an impact on recovery of vegetation cover after fire.

PLANT SPECIES FREQUENCIES

Another objective of this study was to determine the response of plant species to fire in the sagebrush steppe. Plant populations respond to a variety of biotic and abiotic influences such as grazing (West et al. 1979), drought (Pechanec et al. 1937), and fire (Harniss and Murray 1973) and each plant species response may be independent or dependent on the other species around it (West et al. 1979). Although fire was the treatment applied in this study, the responses of plant species to the fire were affected through interactions with other biotic and abiotic factors such as neighboring vegetation, moisture, and aspect.

Within two yr, overall forb and grass cover had returned to before fire levels in both the 2002 and 2003 fires. However, in this relatively healthy and diverse sagebrush steppe community, the fire did result in some increases and decreases in the frequencies of some grass and forb species.

Artemisia tridentata spp. vaseyana, *Festuca idahoensis*, and *Cordylanthus ramosus* were the only three species that had decreased frequencies as a result of the 2002 and 2003 prescribed burns (Figure 4 a-c and Appendices A and B). *A. tridentata spp. vaseyana*, the dominant shrub in this ecosystem, does not sprout back after a fire and few seedlings were observed. Over the next 15 to 20 yr this shrub species will most likely re-establish and dominate the site (Harniss and Murray 1973). Over one third of the *F. idahoensis* plants, a perennial grass species, were killed during the 2002 and 2003 prescribed burns. This decline in frequency has also been observed in others studies (Blaisdell 1953; Conrad and Poulton 1966; Schwecke and Hann 1989; Wamboldt et al. 2001). *F. idahoensis* frequency did not increase in the second and third yr after the fire and may take several decades to fully recover (Harniss and Murray 1973). *C. ramosus*, a perennial forb common in the region, nearly disappeared in the burned areas after the 2002 and 2003 burns.

Hesperostipa comata and *Polygonum douglassii* increased as a response to the 2002 fire (Figures 4d and e). *H. comata*, a perennial grass, is known to be resistant to fire, especially when the fire occurs after August (Wright and Klemmedson 1965). *H. comata* frequencies increased to 60% in the yr following the 2002 fire in the burned plots representing a flush of new plants, but then declined in 2004. In the 2003 burn, *H. comata* frequencies were not altered in both the burned and unburned areas over the course of the experiment (Appendix B). *P. douglassii*, an annual forb, increased in second yr and declined the third year after the burn in both burned and unburned areas in after the 2002 fire. The size of the increase, however, was larger in the burned plots. In the 2003 fire, *P. douglassii* appeared in both burned and unburned areas after the fire. Two other annual forb species (*Chenopodium fremontii* and *Chenopodium leptophyllum*) that could not be analyzed due to lack of sufficient numbers each year, apparently increased as a response to the burn (Appendices A and B). *C. fremontii* appeared in 2004 in both burn areas and then declined in 2005. *C. leptophyllum* appeared the year after each fire and then declined the following year. In the 2003 fire, 3 of the 5 plots in the unburned area had *C. leptophyllum*. Other studies have measured similar short-duration positive responses of *Chenopodium* species to fire (Bartos and Mueggler 1981; Bartos et al. 1994).

Elymus albicans was abundant before the 2002 burn (Figure 4f and Appendix A). Two yr after the 2002 fire, the frequency increased in the burned areas. Three yr after the 2002 fire, the frequency decreased in the unburned areas. In the 2003 burn, there were no *E. albicans* plants in the plots (Appendix B). The year after the fire, frequencies increased in the burned and unburned areas to 80%. *E. albicans* is a rhizomatous species that typically responds positively after fire (Harniss and Murray 1973; Akinsoji 1988). However, in this study the response was mixed. In the 2002 fire burn area *E. albicans* response was delayed a year and in the 2003 fire, the positive response was similar in the burned and unburned areas.

Responses to the 2002 fire were similar in the burned and unburned areas for *Viola nuttallii*, *Microseris nutans*, *Mertensia oblongifolia*, *Poa secunda*, *Koeleria macrantha*, *Allium acuminatum*, *Gayophytum racemosum*, *Carex filifolia*, *Astragalus miser*, *Antennaria rosea*, *Astragalus convallarius*, *Eriogonum heracleoides*, and *Erigeron corymbosus* (Figure 4g-s). Any responses in these species were possibly due to some other biotic or abiotic factor or, more probably, an interaction of factors. Generally, responses of the above plant frequencies in the 2003 fire are similar to the 2002 fire, but there were some exceptions. *A. convallarius*, *C. filifolia*, and *A. miser* all had potentially significant increases in frequency in the burned area compared to the unburned (Figures 4l, 4n, and 4o). Although frequencies of *Eriogonum heracleoides*, and *Erigeron corymbosu* did not vary in this study or in a 1952 fire in southeast Idaho, there was a reported increase in the biomass of these two species three yr after the fire (Mueggler and Blaisdell 1958).

Many increases and decreases of plant species followed earlier studies; many more species have not been reported in the scientific literature. Of particular interest are the perennial grasses *P. secunda* and *K. macrantha* (Figure 4j and 4k and Appendix B), which both increased in frequency after the 2002 and 2003 fires. The increases in frequency were dependent of year, 2004 for *P. secunda* and 2005 for *K. macrantha* and apparently independent of fire. These results for *P. secunda* are consistent with the measurements of Wright and Klemmedson (1965). However the results for *K. macrantha* are different from Antos et al. (1983) which showed increases restricted to burned areas.

There were 70 and 53 species observed in the 2002 and 2003 studies, respectively. Of these, only 3 species had decreased and 3 had increased frequencies. The first year after both fires there were decreases in grass and shrub cover. In the second year after the fires, grass cover had increased to before fire levels in the burned areas, whereas shrub cover would take years to return to before fire amounts. Except for the shrub *A. tridentata spp. vaseyana*, these two mid-September prescribed fires had only transient impacts on plant cover. Wildfire is a natural part of the sagebrush steppe ecosystem (Blaisdell et al. 1982). This study demonstrates that in a sagebrush steppe ecosystem, without significant non-native species or anthropogenic disturbances, plant species frequencies are only minimally altered and the plant community that develops after fire is similar to the one before fire and will most likely result in a return to a sagebrush dominated community (Harniss and Murray 1973; Barney and Frischknecht 1974; Wambolt et al. 2001).

ACKNOWLEDGMENTS

This study was made possible by a grant from the National Aeronautics and Space Administration Goddard Space Flight Center. ISU would also like to acknowledge the Idaho Delegation for their assistance in obtaining this grant. The authors express their appreciation to Scott McCoy, Ada

Williamson, Brad Eddins, Jack Hensley, and fire crews from the USDA Forest Service and the Bureau of Land management for their technical assistance.

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Appendix A. Plant species frequencies in the 2002 burn area and percent of all plots with each species.

Species	Treatment	2002	2003	2004	2005	2002	2003	2004	2005
						---------------%---------------			
Annual forbs									
Amsinckia menziesii	Burned	0	1	0	0	0	2	0	0
Chenopodium fremontii	Burned	0	0	8	1	0	0	20	2
Chenopodium leptophyllum	Burned	0	17	4	0	0	41	10	0
Collinsia parviflora	Burned	7	5	7	0	17	12	17	0
	Unburned	9	7	8	0	18	14	16	0
Cordylanthus ramosus	Burned	17	2	2	1	41	5	5	2
	Unburned	24	10	24	19	48	20	48	38
Gayophytum racemosum	Burned	0	4	19	1	0	10	46	2
	Unburned	2	2	10	3	4	4	20	6
Lepidium densilorum	Burned	0	0	0	2	0	0	0	5
Polygonum douglassii	Burned	8	18	34	26	20	44	83	63
	Unburned	7	4	21	14	14	8	42	28
Tragapogon dubius	Burned	0	0	1	0	0	0	2	0
	Unburned	2	1	1	2	4	2	2	4
Perennial forbs									
Achillea millefolium	Burned	7	6	7	9	17	15	17	22
	Unburned	12	15	17	15	24	30	34	30
Agoseris glauca	Burned	2	0	1	0	5	0	2	0
	Unburned	1	0	2	0	2	0	4	0
Allium acuminatum	Burned	13	7	19	16	32	17	46	39
	Unburned	18	1	14	12	36	2	28	24
Antennaria dimorpha	Burned	0	0	1	0	0	0	2	0
	Unburned	0	0	1	0	0	0	2	0
Antennaria rosea	Burned	21	16	19	12	51	39	46	29
	Unburned	30	30	29	29	60	60	58	58
Antennaria umbrinella	Burned	0	0	1	0	0	0	2	0
	Unburned	0	0	1	0	0	0	2	0
Arabis holboelli	Burned	1	0	0	0	2	0	0	0
Arenaria kingii	Burned	0	0	1	0	0	0	2	0
	Unburned	1	0	3	0	2	0	6	0
Arnica fulgens	Burned	6	2	5	0	15	5	12	0
	Unburned	6	6	9	1	12	12	18	2
Astragalus convallaris	Burned	14	16	11	16	34	39	27	39
	Unburned	15	14	13	7	30	28	26	14
Astragalus filipes	Burned	0	3	0	0	0	7	0	0
	Unburned	0	1	0	0	0	2	0	0

Astragalus lentiginosus	Burned	1	1	2	0	2	2	5	0
Astragalus miser	Burned	9	10	13	6	22	24	32	15
	Unburned	9	4	10	6	18	8	20	12
Calochortus macrocarpus	Burned	0	0	0	1	0	0	0	2
	Unburned	0	0	0	1	0	0	0	2
Cirsium undulatum	Burned	4	1	1	1	10	2	2	2
	Unburned	3	2	2	2	6	4	4	4
Comandra umbellata	Burned	0	0	3	2	0	0	7	5
	Unburned	0	0	6	3	0	0	12	6
Crepis acuminata	Burned	1	0	5	2	2	0	12	5
	Unburned	0	0	2	1	0	0	4	2
Erigeron corymbosus	Burned	28	27	29	27	68	66	71	66
	Unburned	27	26	28	28	54	52	56	56
Erigeron filifolius	Burned	0	1	0	0	0	2	0	0
	Unburned	0	1	1	0	0	2	2	0
Eriogonum heracleoides	Burned	20	14	15	17	49	34	37	41
	Unburned	15	16	18	21	30	32	36	42
Erigeron pumilus	Unburned	0	0	1	0	0	0	2	0
Lomatium foeniculaceum	Burned	0	0	1	0	0	0	2	0
	Unburned	1	0	1	1	2	0	2	2
Lomatium triternatum	Burned	2	0	6	0	5	0	15	0
	Unburned	1	0	5	0	2	0	10	0
Lupinus caudatus	Burned	3	3	4	5	7	7	10	12
	Unburned	4	5	5	13	8	10	10	26
Mertensia oblongifolia	Burned	6	12	19	0	15	29	46	0
	Unburned	4	8	19	0	8	16	38	0
Microseris nutans	Burned	4	0	13	0	10	0	32	0
	Unburned	6	0	15	0	12	0	30	0
Penstemon deustus	Burned	0	1	0	0	0	2	0	0
	Unburned	0	1	1	0	0	2	2	0
Penstemon radicosus	Burned	2	1	3	3	5	2	7	7
	Unburned	0	0	1	0	0	0	2	0
Phlox hoodii	Unburned	0	0	3	1	0	0	6	2
Phlox longifolia	Burned	4	14	16	7	10	34	39	17
	Unburned	10	10	18	6	20	20	36	12
Potentilla gracilis	Unburned	2	2	2	2	4	4	4	4
Ranunculus glaberrimus	Unburned	0	1	0	0	0	2	0	0
Schoenocrambe linifolium	Burned	0	0	1	0	0	0	2	0
Senecio integerrimus	Burned	0	0	1	0	0	0	2	0
	Unburned	0	0	1	0	0	0	2	0
Sphaeralcea munroana	Burned	0	2	0	0	0	5	0	0
Stenotus acaulis	Unburned	1	1	0	0	2	2	0	0

Taraxacum officianale	Burned	0	0	1	1	0	0	2	2
	Unburned	0	0	1	0	0	0	2	0
Tragapogon dubius	Burned	0	0	1	0	0	0	2	0
	Unburned	2	1	1	2	4	2	2	4
Verbascum thapsus	Burned	0	0	1	1	0	0	2	2
	Unburned	1	1	0	0	2	2	0	0
Viola beckwithii	Burned	2	1	5	0	5	2	12	0
	Unburned	5	2	6	0	10	4	12	0
Viola nuttallii	Burned	0	0	12	0	0	0	29	0
	Unburned	1	0	20	0	2	0	40	0
Perennial grasses									
Achnatherum nelsonii	Burned	0	0	0	3	0	0	0	7
	Unburned	0	0	0	5	0	0	0	10
Calamagrostis montanensis	Burned	0	12	1	0	0	29	2	0
	Unburned	0	0	1	0	0	0	2	0
Carex filifolia	Burned	16	12	17	18	39	29	41	44
	Unburned	8	8	11	21	16	16	22	42
Elymus albican	Burned	29	20	36	36	71	49	88	88
	Unburned	43	40	38	24	86	80	76	48
Festuca idahoensis	Burned	31	22	23	25	76	54	56	61
	Unburned	36	39	43	46	72	78	86	92
Hesperostipa comata	Burned	2	25	8	10	5	61	20	24
	Unburned	6	6	3	4	12	12	6	8
Koeleria macrantha	Burned	0	2	3	25	0	5	7	61
	Unburned	4	6	4	22	8	12	8	44
Poa secunda	Burned	15	20	33	34	37	49	80	83
	Unburned	28	23	38	37	56	46	76	74
Pseudoroegneria spicata	Burned	0	0	4	6	0	0	10	15
	Unburned	3	1	5	3	6	2	10	6
Perennial shrubs									
Amelanchier alnifolia	Burned	0	0	0	1	0	0	0	2
	Unburned	0	0	0	1	0	0	0	2
Artemisia tridentata	Burned	31	3	7	5	76	7	17	12
	Unburned	39	40	39	37	78	80	78	74
Chrysothamnus viscidiflorus	Burned	2	4	5	5	5	10	12	12
	Unburned	2	2	1	3	4	4	2	6
Mahonia repens	Burned	2	1	1	1	5	2	2	2
	Unburned	3	3	3	3	6	6	6	6
Opuntia polycantha	Unburned	1	0	1	1	2	0	2	2
Purshia tridentata	Burned	6	3	7	6	15	7	17	15

	Unburned	2	4	3	3	4	8	6	6
Rosa woodsii	Unburned	1	1	1	0	2	2	2	0
Symphoricarpos oreophilus	Burned	1	2	1	1	2	5	2	2
	Unburned	2	3	1	0	4	6	2	0
Tetradymia canescens	Burned	3	6	4	5	7	15	10	12
	Unburned	5	6	5	7	10	12	10	14
Tree									
Larix occidentalis	Burned	1	0	9	0	2	0	22	0
	Unburned	0	0	2	0	0	0	4	0
Unknown									
ARHE	Unburned	0	0	1	0	0	0	2	0

Appendix B. Plant species frequencies in the 2003 burn area and percent of all plots with each species.

Species	Treatment	2003	2004	2005	2003	2004	2005
					-------------	%	-------------
Annual forbs							
Chenopodium fremontii	Burned	0	4	1	0	20	5
Chenopodium leptophyllum	Burned	0	8	0	0	40	0
	Unburned	0	3	0	0	60	0
Collinsia parviflora	Burned	2	8	1	10	40	5
	Unburned	0	0	1	0	0	20
Cordylanthus ramosus	Unburned	2	2	3	40	40	60
Gayophytum racemosum	Burned	1	3	1	5	15	5
	Unburned	0	2	0	0	40	0
Lepidium densiflorum	Burned	0	2	3	0	10	15
Polygonum douglassii	Burned	0	10	13	0	50	65
	Unburned	0	4	3	0	80	60
Tragapogon dubius	Burned	0	1	0	0	5	0
Annual grasses							
Bromus tectorum	Burned	2	3	1	10	15	5
Perennial forbs							
Achillea millefolium	Burned	5	5	3	25	25	15
	Unburned	1	1	3	20	20	60
Agoseris glauca	Burned	0	1	0	0	5	0
	Unburned	0	1	0	0	20	0
Allium acuminatum	Burned	1	3	14	5	15	70
	Unburned	0	1	2	0	20	40
Antennaria dimorpha	Burned	0	1	0	0	5	0
	Unburned	0	1	0	0	20	0
Antennaria rosea	Burned	4	3	3	20	15	15
	Unburned	0	1	1	0	20	20
Arabis holboellii	Burned	0	1	0	0	5	0
Arenaria kingii	Unburned	0	0	1	0	0	20
Arnica fulgens	Burned	0	6	1	0	30	5
	Unburned	0	1	0	0	20	0
Astragalus convallarius	Burned	4	5	3	20	25	15
	Unburned	1	1	2	20	20	40
Astragalus filipes	Burned	2	0	0	10	0	0
Astragalus miser	Burned	0	5	3	0	25	15
	Unburned	0	2	1	0	40	20
Astragalus purshii	Burned	0	1	0	0	5	0
Calochortus macrocarpus	Burned	0	3	4	0	15	20
	Unburned	0	1	1	0	20	20
Cirsium undulatum	Burned	3	0	1	15	0	5
Collomia linearis	Burned	1	0	0	5	0	0
Comandra umbellata	Burned	3	5	6	15	25	30
	Unburned	1	2	1	20	40	20
Crepis acuminata	Burned	3	5	8	15	25	40
	Unburned	1	1	1	20	20	20

Erigeron corymbosus	Burned	8	4	8	40	20	40
	Unburned	4	2	3	80	40	60
Erigeron filifolius	Burned	0	0	1	0	0	5
Eriogonum heracleoides	Burned	16	9	9	80	45	45
	Unburned	4	5	3	80	100	60
Lomatium foeniculaceum	Burned	0	0	2	0	0	10
	Unburned	0	0	1	0	0	20
Lupinus caudatus	Burned	2	3	4	10	15	20
	Unburned	2	2	1	40	40	20
Mertensia oblongifolia	Burned	0	1	0	0	5	0
	Unburned	0	1	0	0	20	0
Penstemon radicosus	Burned	0	1	1	0	5	5
	Unburned	0	1	1	0	20	20
Phlox longifolia	Burned	11	8	8	55	40	40
	Unburned	3	2	2	60	40	40
Sphaeralcea munroana	Burned	0	1	0	0	5	0
Taraxacum oficinale	Burned	0	3	3	0	15	15
	Unburned	0	1	2	0	20	40
Viola nuttallii	Burned	0	1	0	0	5	0
Perennial grasses							
Achnatherum nelsonii	Burned	0	2	0	0	10	0
Calamagrostis montanensis	Burned	0	1	0	0	5	0
	Unburned	0	1	0	0	20	0
Carex douglasii	Burned	0	1	0	0	5	0
Carex filifolia	Burned	0	2	4	0	10	20
	Unburned	0	2	0	0	40	0
Elymus albican	Burned	0	17	16	0	85	80
	Unburned	0	4	4	0	80	80
Festuca idahoensis	Burned	10	7	2	50	35	10
	Unburned	1	3	1	20	60	20
Hesperostipa comata	Burned	9	5	6	45	25	30
	Unburned	3	1	3	60	20	60
Koeleria macrantha	Burned	1	2	13	5	10	65
	Unburned	2	0	2	40	0	40
Leymus cinereus	Burned	1	2	1	5	10	5
	Unburned	0	1	0	0	20	0
Poa secunda	Burned	10	9	12	50	45	60
	Unburned	3	3	5	60	60	100
Pseudoroegneria spicata	Burned	0	0	1	0	0	5
	Unburned	0	2	0	0	10	0
Perennial shrubs							
Atemisia tridentata	Burned	16	7	3	80	35	15
	Unburned	5	3	5	100	60	100
Chrysothamnum viscidiflorus	Burned	3	5	4	15	25	20
Opuntia polycantha	Burned	1	0	0	5	0	0
Purshia tridentata	Burned	1	0	0	5	0	0
Tetradymia canescens	Burned	4	1	3	20	5	15
	Unburned	1	1	1	20	20	20