

# Response of Elk to Changes in Plant Production and Nutrition Following Prescribed Burning

FRED VAN DYKE,<sup>1</sup> *Department of Biology, Northwestern College, Orange City, IA 51041, USA*

JEFFREY A. DARRAGH, *Department of Biology, Wheaton College, Wheaton, IL 60187, USA*

**ABSTRACT** Researchers have ascribed use of areas by grazers after burning to changes in plant community structure, community composition, nutritional quality, and seasonal availability. Researchers can better evaluate these alternatives if they monitor changes in plant communities following burning concurrently with changes in animal use. We examined responses of elk (*Cervus elaphus*) to prescribed burning of areas dominated by sagebrush (*Artemisia* spp.) in south-central Montana, USA, within which we monitored changes in plant production, nutritional quality, and community composition and diversity from 1989 to 1999. Elk increased use of burned sites 1–2 years after burning, then reduced use to levels associated with preburn conditions over the next 3–10 years. Burning transformed low-diversity, sagebrush-dominated communities into relatively high-diversity, grass- and forb-dominated communities that persisted for 10 years, but forage biomass and protein content declined on burned sites after initial short-term increases. Changes in elk use closely tracked changes in production and nutritional quality of plants. Therefore, we concluded that increases in quantity and quality of forage were the primary cause for increased use of burned sites by elk. Managers may observe only short-term responses from elk following burning but can expect longer-term increases in plant diversity and persistence of grass–forb communities on burned sites for >10 years that may be important to elk or other grazing ungulates. (JOURNAL OF WILDLIFE MANAGEMENT 71(1):23–29; 2007)

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Fire affects plant community composition, structure, and function (Wright and Bailey 1982, Briggs and Knapp 2001), and can lead to short-term increases in net primary productivity, particularly in grasslands or shrublands (Blair 1997, Tracy and McNaughton 1997, Turner et al. 1997, Johnson and Matchett 2001). Thus, managers often prescribe fire to sites where increased production might benefit wild or domestic herbivores. Such considerations are important on western rangelands, where in the absence of fire, communities of shrubs such as sagebrush (*Artemisia* spp.) increase and restrict productivity of grasses and forbs that may be of greater forage value for grazers.

Managers do not unanimously view changes in plant community structure and succession from burning as beneficial to conservation and many have increasingly challenged the claim of enhanced forage production following burning in sagebrush communities (Watts and Wambolt 1996, Wambolt et al. 2001). In contrast, other studies have demonstrated increased production of grass and forbs following burning in sagebrush communities (Van Dyke et al. 1991, Tracy and McNaughton 1997, Turner et al. 1997). Many investigators have documented increased use of burned sites by grazing ungulates (Vinton et al. 1992, Biondini et al. 1999), including elk (*Cervus elaphus*; Pearson et al. 1995, Singer and Harter 1996). Other studies also have shown increased use of burned sites by elk, often with improved physiological condition (Rounds 1981, Rowland et al. 1983, Jourdonnais and Bedunah 1990), but opinion is divided as to whether such changes reflect response to improved forage (Turner et al. 1994, Tracy and McNaughton 1997) or changes in structural characteristics of the plant community (Hobbs et al. 1991, Vinton et al. 1992).

We coupled an investigation of changes in plant community structure, production, and nutritional quality following burning of sagebrush in Montana, USA, with concurrent monitoring of elk use over an 11-year period. Our purpose was to provide managers with more accurate and longer-term information about responses of plant communities and elk to prescribed burning, contributing to its more effective use as a management tool. We sought to answer 1) how long would changes in plant community structure and production persist after burning, 2) would such changes be accompanied by increases in plant community diversity, 3) would elk increase use of burned sites if forage production and nutrition increased, and 4) would elk continue to make higher use of burned sites if structural characteristics of plant communities remained distinct, even if forage production and nutrition declined? Through the third and fourth questions, we examined whether elk select foraging sites based on forage or structural characteristics.

## STUDY AREA

Mill Draw, a prominent, east-facing ravine descending from the east face of the Line Creek Plateau in south-central Montana (45°1'N, 109°16'W), is a portion of the annual range of the Line Creek elk population that received use by elk from November through May (Van Dyke and Klein 1996, Van Dyke et al. 1998). Most use occurred in the upper portion of the ravine on lands administered by the Beartooth District of the Custer National Forest, United States Forest Service (USFS). Vegetation in Mill Draw consisted of sagebrush-covered ravine slopes and bottoms, with a scattered overstory of limber pine (*Pinus flexilis*) on the upper portions of slopes, surrounding ridge crests, and at the head of the draw. Such vegetation was characteristic of the

<sup>1</sup> E-mail: fred.g.vandyke@wheaton.edu

entire area and is typical for *Artemisia tridentata*–*Festuca idahoensis* plant communities (Mueggler and Stewart 1980). Most sagebrush was *Artemisia tridentata* ssp. *vaseyana*, but *Artemisia arbuscula* ssp. *arbuscula* also was present on drier sites. Other shrub species were rare. Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) were the most common grasses interspersed among or beneath sagebrush overstory. Other frequently encountered but less common species of grasses included various bluegrasses (*Poa* spp.), needle-and-thread grass (*Hesperostipa comata*), and king fescue (*Leucopoa kingii*). Common forbs included various species of milkvetch and locoweed (*Astragalus* spp.) and various species of phlox (*Phlox* spp.).

The climate was characterized by short, cool summers and long, cold winters. Average January temperature at Red Lodge, Montana, USA, the closest town to the study area, was  $-6^{\circ}\text{C}$ , and average annual precipitation was 56 cm, mostly in the form of snow from November through May (Van Dyke et al. 1991).

There were no livestock on USFS land in Mill Draw, nor were there any human residences or activities. Roads to Mill Draw were primitive, not maintained, and covered with large rocks, which discouraged vehicular travel. Even these roads were closed to the public before the final year of the study in 1999. Aside from Forest Service personnel, the senior author, and various seasonal field assistants, human visitation to the area was low and primarily limited to recreational hikers during spring and summer and to hunters who entered the area by foot or horseback in autumn.

## METHODS

### Field Measurements

United States Forest Service personnel selected Mill Draw as a suitable area for a prescribed burn in 1989. In April of that year, Forest Service personnel burned approximately 50 ha of sagebrush within Mill Draw and left approximately 200 ha of the draw unburned. We established 5 permanent  $404\text{-m}^2$  plots ( $20.1\text{ m} \times 20.1\text{ m}$ ) within the burned area and 5 placed within the unburned portion in June 1989. We established plots only on sites with  $\leq 35\%$  slope because fire history and topographic position of a site are often interactive in their effects on plant production (Turner et al. 1997), and observations of elk in the area indicated that animals fed primarily on slopes of  $< 35\%$  (Van Dyke et al. 1991). We selected burned and unburned plots to be as similar to one another as possible in slope, aspect, preburn vegetation, and disturbance and management history. A wildfire in 1991 burned most of the previously unburned portion of Mill Draw, including formerly unburned plots, rendering them unsuitable for further use as controls. In the unburned remnant of approximately 10 ha, we established 3 new plots for measuring unburned vegetation in 1993.

Ungulates may increase their use, duration, and number of foraging bouts in habitat patches that are more profitable (Baker and Hobbs 1982, Collins and Urness 1983, McNaughton 1984). Therefore, we choose elk use-days (EUD) as the best index to express the combined effect of

the duration and intensity of elk foraging in a plot. In June 1989–1991, 1993, and 1999, after elk had left Mill Draw and moved to higher-elevation summer ranges, we estimated elk use in each plot by counting the number of elk pellet groups within 1 m of 6 randomly selected 20.1-m transects laid perpendicular to the baseline of each plot, thus permitting a calculation of pellet group density. We spray-painted and scattered pellets after counting to avoid repeat counting in subsequent surveys. We converted the estimated density of pellets to an index of EUD by dividing the estimate of density by 13 (Hayden-Wing 1979). We stress here that although Hayden-Wing used such a conversion to estimate density, we did not. We used the elk pellet values only as a comparative index of site-specific elk use, not as a measure of numbers of elk on the site or in the local population to permit comparisons of our data with other studies that have used pellet numbers as density indices.

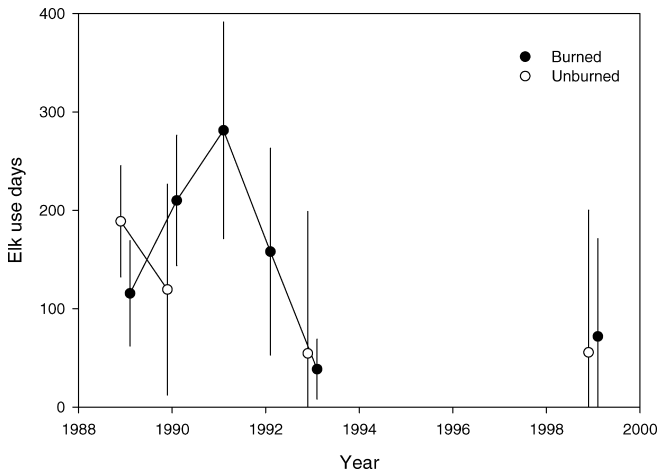
We determined vegetation coverage by species concurrently with determinations of elk use in June of each year. In this effort, we determined the percent cover of each species within  $25.4 \times 50.8\text{-cm}$  calibrated (Daubenmire) frames placed at 5 randomly selected locations along each transect, 30 total frames per plot. From 1989 to 1992 we sampled vegetation coverage on only one plot per treatment. In 1993 and 1999 we sampled vegetation in all plots and treatments.

At the end of the growing season in late August from 1989 to 1992 and in 1999, we clipped and sorted graminoids and forbs collected from a subset of randomly selected plots in each treatment for nutritional analysis. We considered graminoids and forbs to reflect the quantity and quality of most of the forage consumed by elk during their time on these sites because we knew that shrubs composed only a small part of elk winter diets on this range (Van Dyke et al. 1991). Therefore, we concentrated nutritional analyses on graminoids and forbs. We used plant samples to estimate plant production (kg/ha, dry wt), moisture, and protein (percent dry wt). We determined moisture levels by air-drying and used them to estimate dry weight of samples, which we then converted to dry weight estimates of plant production. We determined protein levels by standard procedures (Association of Official Analytical Chemists 1965) at the Analytical Chemistry Laboratory of the Agricultural Experiment Station of Montana State University (Bozeman, MT).

### Quantitative and Statistical Analysis

To evaluate short-term effects of burning on elk use of Mill Draw sites, we compared the difference in mean EUD on the same plots from 1989 to 1990 (short-term effect) and from 1993 to 1999 (longer-term effect) between burned and unburned treatments through 2-sample *t*-tests. In addition to this direct comparison between burned and unburned plots in the same time periods, we also made a more continuous assessment of time-specific responses of elk to burning by comparing differences in EUD only on burned plots in successive years from 1989 to 1993 and in 1999 through a 1-way analysis of variance (ANOVA).

To evaluate longer-term effects of prescribed burning on



**Figure 1.** Long-term elk use on 5 404-m<sup>2</sup> burned and unburned plots. Burned plots ( $n = 5$ ) were burned in 1989 in plant communities originally dominated by sagebrush in south-central Montana, USA. Elk use was measured annually from 1989 to 1993 and in 1999. Bars represent 95% confidence intervals.

plant communities, we compared mean differences from 1993 to 1999 in percent coverage (arcsine transformed) of graminoids, forbs, and sagebrush in the same plots on burned and unburned treatments using 2-sample  $t$ -tests. We compared confidence interval estimates (95% CI) of coverage in these categories in 1993 and 1999 to single (1 plot) estimates of coverage from 1989 to 1992 to assess differences between short- and longer-term plant responses. Although such a comparison is not a test of statistical significance, it does provide a quantitative assessment of differences in coverage between the 2 time periods.

To evaluate changes in plant community characteristics in response to treatment, we determined species richness (no. of plant species) and community diversity (Shannon Index) from coverage data. We compared species richness and community diversity between 1993 and 1999 using 2-way ANOVA with treatment (burned or unburned) and time (yr after burning) as factors. We compared richness and diversity of these years to years from 1989 to 1992 using methods previously described for plant coverage.

To assess quantity and quality of forage on burned and unburned sites in the short-term, we compared changes in graminoid and forb production, and protein content on burned and unburned plots from 1989 to 1990 using a 2-

way ANOVA. To assess the effects of time after burning on the pattern of change in forage production and protein levels on individual sites, we evaluated forage production and protein exclusively on burned plots from 1989 to 1992 and in 1999 using a repeated-measures ANOVA. Finally, to assess differences between burned and unburned plots in the longer term, we compared treatment differences in graminoid and forb production, and protein content in 1999 (10 yr after burning) via separate 2-sample  $t$ -tests.

## RESULTS

### Changes in Elk Use

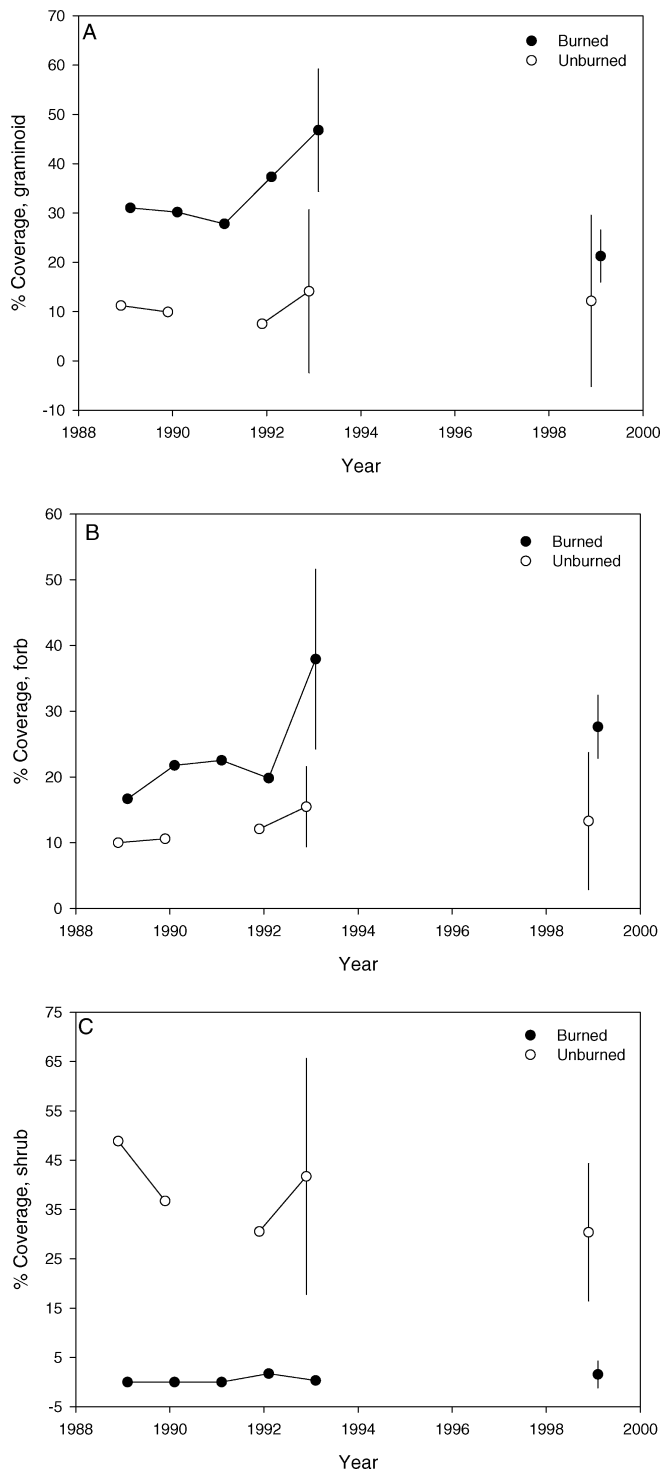
In the short-term, elk use on burned plots increased by an average of 94.4 EUD (SE = 18.4) from 1989 (immediately after burning) to 1990 (1 yr after burning), compared to an average decrease of 69.4 EUD (SE = 45.1) on unburned plots during the same period ( $t_8 = 3.36$ ,  $P = 0.001$ ). In the longer term, elk use increased on burned sites over time ( $F_{5,24} = 9.09$ ,  $P < 0.001$ ), rising from an initial level of 115.6 EUD (SE = 19.3) immediately after burning (1989), to a peak of 281.3 EUD (SE = 39.6) within 2 years (1991). From 1991 to 1993, EUD declined to lower levels similar to those recorded immediately after burning and consistent with elk use documented 6 years later in 1999 (Fig. 1). Differences between treatments had declined by 1993, and by 1999 they were insignificant ( $t_6 = 0.58$ ,  $P = 0.58$ ).

### Changes in Plant Communities

Annual estimates of average species richness in plant communities ranged from 3–62% higher and diversity 39–88% higher on burned sites (richness:  $F_{1,4} = 7.32$ ,  $P = 0.02$ ; diversity:  $F_{1,4} = 76.32$ ,  $P < 0.0001$ ), but differences were not influenced by year (richness:  $F_{1,4} = 0.02$ ,  $P = 0.97$ ; diversity:  $F_{1,4} = 1.30$ ,  $P = 0.28$ ), nor were there any year  $\times$  treatment interactions (richness:  $F_{1,4} = 0.80$ ,  $P = 0.39$ ; diversity:  $F_{1,4} = 0.03$ ,  $P = 0.88$ ). Thus, prescribed burning transformed sagebrush-dominated communities of relatively low diversity into grass- and forb-dominated communities of relatively high diversity, and such transformations persisted for up to 10 years after burning (Table 1). From 1989 to 1992, single-plot estimates of species richness and diversity on burned sites fell within range of variation observed in 1993 and 1999 (richness: 28–34; diversity: 2.21–2.43), as did single-plot estimates of these variables on unburned sites (richness: 21–29; diversity: 1.29–1.59),

**Table 1.** Long-term responses in characteristics of vegetation communities on burned and unburned plots originally dominated by sagebrush in south-central Montana, USA, 1993 and 1999. Two-way analysis of variance.

Characteristic	1993				1999				Treatment		Yr		Treatment $\times$ yr	
	Burned		Unburned		Burned		Unburned		$F$	$P$	$F$	$P$	$F$	$P$
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE						
Species richness	31.4	1.6	23.3	1.9	28.0	2.5	25.3	2.9	3.88	0.10	0.14	0.72	2.11	0.20
Shannon Index	2.34	0.13	1.58	0.11	2.48	0.11	1.70	0.06	28.26	<0.01	2.14	0.19	0.02	0.88
Graminoid coverage (%)	46.8	4.5	14.1	3.9	21.2	1.9	12.2	4.0	20.31	<0.01	22.52	<0.01	14.13	<0.01
Forb coverage (%)	37.9	4.9	15.5	1.4	27.6	1.7	13.3	2.4	28.80	<0.01	3.15	0.13	0.89	0.38
Sagebrush coverage (%)	0.3	0.2	41.7	5.6	1.5	1.0	30.4	3.6	630.01	<0.01	0.40	0.55	3.17	0.13



**Figure 2.** Graminoid (A), forb (B), and sagebrush (C) coverage associated with plant communities on burned and unburned 404-m<sup>2</sup> plots originally dominated by sagebrush in south-central Montana, USA. Samples from 1989 to 1992 are single estimates (one plot sampled/treatment). Bars associated with means in 1993 and 1999 reflect 95% confidence intervals associated with multiple plot samples.

exhibiting the same pattern of treatment differences observed in 1993 and 1999. Coverage of graminoids on burned plots increased up to 47% and forbs up to 118% following removal of sagebrush and was consistently higher on burned plots compared to unburned plots in any given

year (Fig. 2A,B). Forb coverage remained at elevated levels up to 10 years after burning, and the change in forb coverage from 1993 to 1999 was similar on burned and unburned plots ( $t_6 = 1.12$ ,  $P = 0.31$ ). In contrast, grasses, although having nearly 4 times more coverage on burned sites than on unburned sites in 1993 (46.8% to 12.2%), declined 54% (46.8% to 21.3%) on burned plots ( $t_6 = 4.26$ ,  $P = 0.0053$ ). By 1999 such declines led to similar levels of graminoid coverage in both treatments (Fig. 2A). Sagebrush, which contributed 42% of coverage on unburned sites, was essentially eliminated on burned sites (<1.0%) and showed no evidence of reinvasion through 1993 (Fig. 2C). From 1993 to 1999 sagebrush coverage declined on unburned sites (-11.3%, SE = 8.5) while increasing on burned sites (1.2%, SE = 1.1;  $t_6 = -1.96$ ,  $P = 0.10$ ; Fig. 2C).

### Changes in Forage Quantity and Quality

As burned plots aged, total forage production and protein levels declined (Table 2). Graminoid protein levels peaked immediately after burning in 1989 and forage (graminoid plus forb) production peaked 1 year after burning in 1990, but production varied, with peaks of grasses and forbs occurring later and in different years. Considered concurrently, peak elk use on burned sites (1991) occurred after peaks in forage production (1990) and protein (1989; Table 2). Elk use subsequently declined with concurrent declines in these variables, falling below preburn use levels by 1993 (Table 2, Fig. 1). By 1999, forage production and forb protein levels were no longer different on burned and unburned sites (Table 3) and, although burned sites remained higher in graminoid protein, elk use remained low on burned and unburned sites (Table 2, Fig. 1).

### DISCUSSION

Two of our primary objectives in this study were to determine how long changes in vegetation production, nutritional quality, and structure in a sagebrush community would persist after burning, and would they be accompanied by increases in plant community diversity. Our results provided definitive answers to these questions. Burning increased plant production and nutritional quality on these formerly sagebrush-dominated sites, and such increases were accompanied by increases in species richness and diversity of the plant community. Changes in structure and composition of the vegetation community were persistent for 10 years, but elevated plant production and protein levels on burned areas were not.

The temporary increases in production and forage are results relevant to our remaining questions. First, would elk use of burned sites increase as forage production and nutritional quality increased? Second, would elk continue to make higher use of burned sites if structural changes in vegetation persisted, even as production and nutritional quality declined? Again, our results offer definitive answers. Elk use increased on burned sites as forage production and protein levels rose but declined as protein levels declined. Although protein levels in grasses on burned sites remained higher than on unburned sites up to 10 years after the

**Table 2.** Concurrent changes in production (kg/ha) and protein (percent dry wt) in graminoids and forbs and in elk use-days/ha (EUD) on burned plots originally dominated by sagebrush in south-central Montana, USA, in 1989–1993 and 1999. One-way analysis of variance.

	Yr												F	P	
	1989		1990		1991		1992		1993		1999				
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE			
Graminoid															
Production	557.50	122.00	1,544.14	158.89	966.90	92.03	1,748.12	367.49			845.07	166.93	10.82	<0.01	
Protein	10.00	0.38	7.70	0.60	6.06	0.06	6.06	0.50			6.47	0.09	11.80	<0.01	
Forb															
Production	194.90	74.80	438.98	93.05	447.36	30.67	229.40	39.00			432.37	99.17	3.07	0.05	
Protein	10.35	0.65	9.86	0.29	7.56	0.38	10.60	0.58			7.47	0.72	9.08	<0.01	
EUD	115.60	19.27	210.00	23.86	281.30	39.65	157.96	37.87	38.56	10.99	71.84	35.75	9.09	<0.01	

prescribed fire, they fell significantly from their peak levels immediately after the burn. The pattern of decline in graminoid protein on burned sites in our study was consistent with declines documented on other burned sites in this area, as was the pattern of decreased elk use of sites on which such declines occur (Van Dyke et al. 1991, 1996). Although burned sites remained structurally and compositionally distinct from unburned sites, they failed to retain higher levels of elk use once forage production and nutritional quality declined from peak levels.

Elk influence plant community composition and grazing by elk can have a depressing effect on plant production (Hobbs et al. 1996); however, studies of similar plant communities in this region have shown no detrimental effect of elk grazing on plant production on recently burned sites (Tracy and McNaughton 1997). If elk were the cause of production declines in our study, increasing elk use should, at least initially, have coincided with decreases in plant production. Therefore, when elk use declined after 1991, production should have recovered. This was not the case. Declines in elk use followed declines in plant production, suggesting that elk might have tracked changes in production but did not regulate them. At moderate intensities, grazers stimulate grass production by reducing litter accumulation (Frank and Groffman 1998). Thus, it is possible that declines in elk use over time may have contributed to declines in grass production and grass coverage observed on burned sites.

**Table 3.** Differences in production (kg/ha) and protein (percent dry wt) in graminoids and forbs on burned and unburned plots originally dominated by sagebrush in south-central Montana, USA, in 1999, 10 years after burning. Unpaired *t*-test, *df* = 4 for comparisons of grasses, *df* = 3 for forbs.

	Burned		Unburned		t	P
	$\bar{x}$	SE	$\bar{x}$	SE		
Graminoid						
Production	845.07	166.93	772.10	208.82	0.27	0.80
Protein	6.47	0.09	5.30	0.40	2.82	0.05
Forb						
Production	462.37	99.17	379.05	64.35	0.61	0.59
Protein	7.47	0.72	8.15	0.25	-0.72	0.52

The changes we observed on burned sites followed the typical pattern of grass invasion and domination after fire, a trend attributable to superior establishment capabilities of grasses on disturbed areas, to removal of accumulated litter from sagebrush that may have inhibited germination by other species (McGinley and Tilman 1992), and to the capacity of grasses to rapidly increase plant density under favorable conditions (Briggs and Knapp 2001). The increased contribution of forbs to total coverage that we observed also was a pattern observed on recently burned sites (Harniss and Murray 1973, West and Hassan 1985, Briggs and Knapp 2001).

Previous investigators have offered various explanations for elk selection of burned sites. Some (Hobbs et al. 1991, Vinton et al. 1992) have asserted that elk select burned sites primarily because of structural characteristics and plant species composition. Others have suggested that enhanced nutritional quality (Van Dyke et al. 1991, Turner et al. 1994, Tracy and McNaughton 1997) or earlier seasonal availability (Biondini et al. 1999) of vegetation on burned sites are the factors that most strongly influence selection. Although production of grasses declined in our study, burned sites persisted as grass-forb communities through 1999. If elk made site selections based on structural differences, use of burned sites should have remained high. Because elk use declined on sites with similar vegetation structure, but with lower levels of forage production and nutritional quality, we conclude that elk determined their time on-site primarily in response to quantity and quality of forage, not to structural composition of the plant community.

## MANAGEMENT IMPLICATIONS

Based on the outcomes of this investigation, we conclude that managers can apply prescribed burns in sagebrush communities to benefit elk through increased forage quantity and quality, but such benefits may persist  $\leq 2$  years under conditions similar to our study. Although prescribed burning in sagebrush can be of benefit to grasses, forbs, and wildlife, we caution managers against the view that burning is beneficial to all conservation objectives. Elevated plant production and protein levels observed in infrequently

burned sagebrush communities are typically short-term responses, and even short-term effects do not always occur (Wambolt et al. 2001). Large-scale removal of sagebrush is likely to lower habitat and landscape (beta) diversity, reduce populations of indigenous species, and fail to provide managers opportunity to evaluate differences in plant and animal responses between sagebrush and non-sagebrush communities. In fact, models relating fire, grazing, and landscape characteristics predict that prescribed fires affecting  $\geq 60\%$  of winter range will produce no site-specific responses in ungulates and may reduce winter survival (Turner et al. 1994).

For optimal benefits to elk and other grazing ungulates, and to achieve increased biodiversity in native plant communities, we recommend that managers employ small, dispersed burns, like those applied in this study, and disperse burns widely in space and time. Such dispersion permits ungulates to have ongoing accessibility to newly burned sites that provide greater increases in plant production and nutritional quality compared to older burns and unburned sites on larger landscape scales, and permits managers opportunity for greater monitoring precision in assessing their effects.

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