EFFECTS OF PRESCRIBED GRASSLAND BURNS ON FORAGE AVAILABILITY, QUALITY AND BIGHORN SHEEP USE

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Abstract: We assessed the usefulness of prescribed grassland burns to improve bighorn sheep habitat in southwestern Alberta over a 4-year period (1994-1997). We conducted prescribed grassland burns in April 1995, 1996, and 1997. Burning decreased biomass of dead vegetation and increased live vegetation biomass. In all years, burning increased the crude protein content of vegetation up to mid-June. Protein content 1 year after the burn did not differ on burn and control plots. Bighorn sheep increased their use of burned areas by 2 to 5 times in spring and fall. There was no sex difference in the use of burn and control plots. In May, bite rates of sheep foraging on burns were higher than on controls, but in September bite rates were similar on burns and controls. On burns, males had a higher bite rate than females, while on controls females had a higher bite rate than males. There was no difference in fecal crude protein content of the forage selected by males and females. Grassland burns had a short-term positive effect on forage quality and probably improved sheep nutrition.

Keywords: foraging behaviour, forage quantity, quality, *Ovis canadensis*

In recent years, prescribed burning of grasslands and aspen (*Populus tremuloides*) has been used as a tool to improve habitat for ungulates such as bighorn sheep (*Ovis canadensis*), elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) and to reduce the spread of trembling aspen (Stoeckeler 1960, Perala 1974, Svedarsky et al. 1986, Weber 1990, Peck and Peek 1991, Smith et al. 1999).

Bighorn sheep are mainly grazers, and rely on grassy south-facing slopes close to escape terrain, especially in winter (Shannon et al. 1975, Hofmann 1989). Grassy meadows that are not heavily grazed can accumulate a thick layer of dead vegetation, reducing the production of new vegetation each spring by preventing light from reaching the growing shoots. Dead grass is of poor quality and recent studies on bison (*Bison bison*), mule deer, white-tailed deer (*Odocoileus virginianus*) and bighorn sheep have shown that these ungulates preferred burned over control sites because burning increased diet quality (mainly protein content) and plant production (McWhirter et al. 1992, Shaw and Carter 1990).

Stelfox (1971) suggested that widespread wildfires around the beginning of the twentieth century resulted in higher-quality sheep ranges and therefore increased sheep numbers. Controlled burning of grasslands may therefore benefit ungulates by increasing biomass and quality of newly available forage (McWhirter et al. 1992). If controlled burning of grassland increased forage protein content and biomass, bighorn sheep should increase their use of burned sites. Little is known about the effects of controlled burning on bighorn sheep winter ranges and no studies have assessed how burns are used by different sex-age classes. It is also unclear whether any beneficial effects are long lasting or are limited to the year of the burn.

In an attempt to restore traditional grazing grounds for bighorn sheep, we carried out prescribed grassland burns on 3 different sites. We were interested in the effect of burning on the biomass and protein content of the forage available to bighorn sheep. Prescribed burns were performed in spring. We expected burned areas to offer new-growth forage earlier in the season and to produce forage of higher protein content compared to control areas, at least in the short term.

In observing the foraging behaviour of sheep, we tested how sheep habitat selection and foraging behaviour were affected by changes in forage quantity and quality on burned and unburned plots. We predicted that sheep would prefer burned plots over control plots and that sheep foraging on burns would have a higher bite rate than on the control because high quality forage is easier to process and more vegetation can be ingested per minute (Robbins 1993).

We also examined whether differences in sheep habitat selection changed seasonally with forage availability and quality. Finally, experimentally-induced variability in forage protein content was used to examine potential differences in foraging strategy of sheep according to sex. Several studies propose that females, due to their generally lower digestive efficiency compared to males and higher energy requirements during gestation and lactation, will be forced to select high-quality forage, while males do not face these constraints (see Main et al. 1996 for a summary). We therefore predicted that proportionally more females than males would use the burned areas, especially in spring when high protein forage is available. Consequently, fecal crude protein content was predicted to be higher in females than in males. Although we expected more females than males to prefer burns in spring (because of high protein content in the forage on the burn), we did not expect to find any sex-biased use of burns in September because protein content by that time would likely be low.

STUDY AREA

The Sheep River Wildlife Sanctuary was established in 1973 to protect bighorn sheep winter range in the foothills of the Rocky Mountains in southwestern Alberta (50° N, 114° W; 1420-1740 m. elevation). It includes open south-facing slopes and grassy meadows, intermixed with aspen copses and coniferous forest, mainly white spruce (*Picea glauca*) and lodgepole pine (*Pinus contorta;* Boag and Wishart 1982). The Wildlife Sanctuary is also an important winter range for elk and mule deer. In winter, the grassy slopes are frequently cleared of snow by warm Chinook winds, making forage easily available to ungulates.

During this study, all sheep (between 88 and 95 individuals) were either individually marked with plastic ear tags (98% of sheep) or recognisable by horn characteristics. Females and males used the same foraging areas in the Wildlife Sanctuary (Ruckstuhl 1998).

METHODS

Burns

The first grassland burn (Missing Link Mountain (MLFE), surface to be burned: ca.

100 x 50m, control surface 50 x 50 m) was done on 7 April 1995 on a south-facing slope at about 200 meters from escape terrain. The second burn (Hay Field, surface burned: ca. 150 x 250m; HF control surface: ca. 100 x 150m) was done on 29 April 1996 on a flat area, adjacent to escape terrain. The third burn, on a south-facing slope with adjacent escape terrain (Windy Point Mountain (WPE), surface burned: ca. 250 x 500m; the WPE control: ca. 100 x 150m), was done on 6 April 1997. Burn and control sites were chosen randomly, but adjacent to each other, with similar slopes, exposure and vegetation types. All 3 burns were situated within the Sheep River Wildlife Sanctuary on areas regularly grazed by bighorn sheep. The burn areas were surrounded by forest (WPE and MLFE) or cut off by a road (HF (north end) and WPE (south end)). Within each of these areas one side of the site was burned, the other left untouched. The burned areas were all large enough to attract groups of grazing bighorn sheep.

Bighorns were present (at least weekly) in all 3 years on all 3 sites in spring and fall. We limited our experiment to 3 different burns due to the following logistic problems: a)Fires had to be set by fire experts and needed the help of the Department of Forestry and the Department of Fish and Wildlife; b) A firefighter crew (at least 10 people) had to be present and ready in case the fire went out of control; c) Fires needed to be done at the right time, ideally, before spring green-up and when the ground was still a little wet from the snow melt; and d) Days with high wind speeds, which are common in the area, had to be avoided as potential days for burning. Due to these problems, only 1 burn was done in each year.

We monitored all burn and control sites from April to October 1994-1997 for sheep use, and each burn and control in the year of the burn and 1 year after for biomass production and protein content. Data from 1994 were used to control for site differences and time effects in sheep use and vegetation quality.

Forage quality and quantity

To estimate forage quality (percent crude protein) and quantity (biomass of dried vegetation) available to sheep, vegetation samples were collected from each burn and adjacent control site. At each site, 5 random samples (25x25 cm quadrates) of vegetation were clipped to the ground twice a month from May to July and once a month in August and September for a total of 8 sampling dates during each growing season (1995-1997). Samples were oven dried at 50^{o} C, weighed for total biomass, and later analysed for crude protein content with the Kjeldahl method (Robbins 1993). To measure the effect of burning on live biomass production, we separated the clipped vegetation of the MLFE burn in 1995 into dead and live forage.

Sheep use

Bighorn sheep used the Wildlife Sanctuary year-round, although in May ewes migrated to alpine areas about 12 km west of the Sanctuary to lamb. During summer they returned for short visits to the Wildlife Sanctuary, but were in the alpine areas most of the time until they migrated back to the Sanctuary in August and September (Festa-Bianchet 1986a, 1988; Ruckstuhl 1998; Ruckstuhl and Festa-Bianchet 1998). Although, in the past rams migrated to the alpine in summer (Festa-Bianchet 1986b), they apparently did not use the alpine areas during our study. Instead, rams often used low foothill areas east of the Wildlife Sanctuary.

To measure sheep use, burned and

control areas were searched daily. The location, time of day, and identification of all sheep were noted. The entire Sanctuary was censused once a week, to determine how many sheep were present. Sheep were generally easy to find in the Sanctuary (Festa-Bianchet 1986a). Fresh droppings left by individually known sheep were collected in April and May 1995 and 1996 to measure sexual differences in diet choice (fecal protein content). Fecal protein content was analysed using the Macro-Kjeldahl method (Robbins 1993). Sheep roamed freely and were feeding on other sites as well as on the burns. Therefore, data on fecal protein content will reveal the average diet choice by males and females regardless of the site they were feeding on. However, if females chose higher quality forage, it should be reflected in their fecal protein content.

Foraging behavior

In 1995 and 1996 we counted the number of bites sheep of both sexes took on the burn and control patches. For these observations, a focal animal was randomly chosen from a group of sheep grazing on either the burn or control. We counted the number of bites per minute during 10 1-minute focal samples. These 1-minute samples give a good estimate of the average number of bites taken by each individual per minute grazing.

Statistical analyses

All data were tested for normality and homoscedasticity using the SPSS statistical package (Norusis 1993). Non-parametric statistics were applied when data were not normally distributed and no transformation resulted in a normal distribution. As elevation, exposition and slopes are different for the 3 burns, data were analysed separately instead of in a multiple test. The effect of burning on vegetation protein content was thus analysed using Mann-Whitney U-tests, comparing control and burn plots for each of the different burn sites separately (Sokal and Rohlf 1995). All means are given with standard deviation.

Only a few sheep were found in the Wildlife Sanctuary between July and August. Hence, we only tested for sex-biased use of burn and control plots in April, May, and September when most rams and ewes were present. To describe seasonal sheep use of burn and control plots (independent of sex), we used the number of sheep observed on different plots per day, when sheep were present in the Wildlife Sanctuary. Differences in the number of individual sheep using burned and control plots each month were tested with Chi-square (Sokal and Rohlf 1995).

To correct for the higher number of females in the population, compared to males, we divided the total number of males or females that used a specific plot by the number of sheep of the same sex in the population for that year (excluding lambs). In 1994 we had 55 adult females, 35 males, and 5 yearlings. In 1995, the ratio was 54:37:11, in 1996 it was 51:36:7, and in 1997 the female, male, yearling ratio was at 36:36:16. We tested for sexual differences in plot use with Mann-Whitney U-tests (Siegel and Castellan 1988). Sexual differences in diet choice, measured as fecal crude protein content, were analysed with Mann-Whitney U-tests. Sexual differences in number of bites taken on burns and differences in number of bites taken on burns and controls were analysed using ANOVA.

RESULTS

Effects of burning on forage protein content and biomass

Prior to any of the burns in 1994, crude protein content varied seasonally, from May to by September, but was the same among the 3 burn sites (Kruskal-Wallis 1 way ANOVA (site as independent variable), χ^2= 0.38, df=2, *P*= 0.83). Crude protein content was highest in May and June with 12.9% (range 9.7-14.5% for all sites) and decreased to 7.0% (range 4.2-11.6% for all sites) by September.

Crude protein content of vegetation taken from the 1995 MLFE burn was higher than from the control from May to mid-June (*Z*= -5.41, *P*< 0.001, *n*= 40) (Figure 1). After June there was no significant difference in crude protein between the control and burn (*Z*= -1.34, *P*= 0.18, *n*= 120). Crude protein content decreased as the season progressed (Kruskal-Wallis 1-wayANOVA: χ^2= 73.83, df=4, *P*< 0.001, *n*= 160).

As with the MLFE burn, crude protein content of vegetation on the 1996 HF burn was higher than on control plots up to mid-June (*Z*= -7.40, *P*< 0.001, *n*= 85) (Figure 1). There was no difference in crude protein content of vegetation between burn and control from July through September (*Z*= -0.60, *P*= 0.55, *n*= 100). Protein content decreased during the summer (Kruskal-Wallis 1-wayANOVA: χ^2= 128.09, df=7, *P*< 0.001, *n*= 185). Crude protein content of the 1997 WPE site was higher on the burn than on the control up to August (*Z*= -3.99, *P*< 0.001, *n*= 30). The WPE was not sampled in May, but crude protein content in June was similar to crude protein content found on the MLFE burn and HF burn sites in burn years (10.4±1.2% on WPE burn; 7.0±1.1% on WPE control) (Figure 1). Protein content of vegetation in August was still high on the WPE burn (8.3±0.9%)

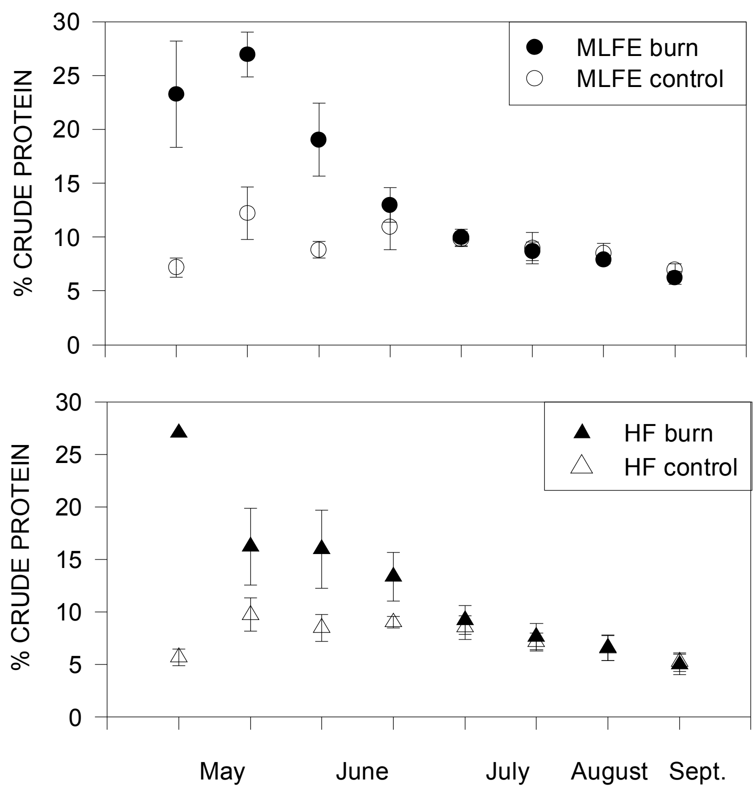

Figure 1: Percent crude protein content of vegetation of control and burn plots on the MLFE site from May to September 1995, and the HF site from April to September 1996. The MLFE site had been burned on April 7, 1995. The HF site was burned on April 29, 1996.

compared to the control (6.5±0.7%) (Z= -2.40, P< 0.05, n= 10).

One year after the burn at MLFE, crude protein (CP) content of vegetation on the burn had returned to pre-burn levels, with a yearly average of 6.2% CP and a range between 3.0% and 11.8% CP. Crude protein content on the control (10.0±1.2% CP) was higher than on the burn (7.0±1.0% CP) in July (Z= -2.95, P< 0.01, n= 20), but not in other months. Protein content decreased over summer (Kruskal-Wallis 1-way-ANOVA: χ^2= 44.18, df=7, P< 0.001, n= 80). The same pattern was observed for the HF burn. One year after the HF burn there was no difference in crude protein content on burned (8.0±1.8% crude protein, n= 10) and control (8.2±1.6%, n=10) patches (Z= -0.80, P= 0.43). Two years after burning crude protein content of vegetation on the MLFE site was higher on the control (7.0±0.4% CP) than on the burn (5.5±0.7% CP) in July (Z= -2.45, P= 0.014) but not in other months (highest Z-value= -1.78, P = 0.075, in August).

In 1995, burning resulted in lower total forage biomass on burns compared to controls up to August. In May, dry weights of vegetation samples taken from 25 x25 cm quadrats on MLFE were, on average, 10.1±1.1 grams for burn samples compared to 34.1±2.0 grams for control samples. By mid-August, total biomass of dried vegetation had reached control levels (both at 37.0±0.8 grams/25 x 25 cm). In September, biomass on burns was around 45.2±1.6 grams and on the controls 35.2+1.4 grams. A similar pattern was observed for the 1996 HF burn, where total biomass was practically zero after burning, but reached control levels by the end of July (Figure 2). One year after the MLFE burn, total biomass on burns and controls was similar (Figure 2).

In the year of the burn, biomass of live vegetation on the MLFE site was initially similar on the burn and control plots, up to August (Z= -1.27, P= 0.21, n= 36; Figure 3). While live biomass continued to increase up to September on the burn, there was a marked drop in live vegetation biomass on the control after August (Z= - 2.23, P<0.05, n= 35; Figure 3).

Effects of burning on sheep's plot choice and foraging behaviour

The sheep preferred to forage on new burns compared to control plots in all years (Table 1). All burns were done in April, and the MLFE burn produced only grass from May onwards, when the burn was preferred over the control site (Table 1). Sheep left the Wildlife Sanctuary in mid-to-late May but again used the burn extensively in September. The HF and the WPE plots were heavily used and were preferred grazing sites of sheep both in pre-burn and burn years. On the HF sheep preferred the burn plots over the control plots in all but 2 months of 1994 to 1996 (Table 1).

The number of sheep per day that used the different burn and control plots in pre- and burn years varied considerably between months (Figures 4-6). Sheep use was highest on all burns in spring, especially for HF (Figure 5) and WPE (Figure 6). The MLFE site was rarely used the year before and the year after the burn was done (Figure 4). The HF was still heavily used 1 year after the burn in 1997 and more sheep were on burn than on control plots (Table 1, Figure 5).

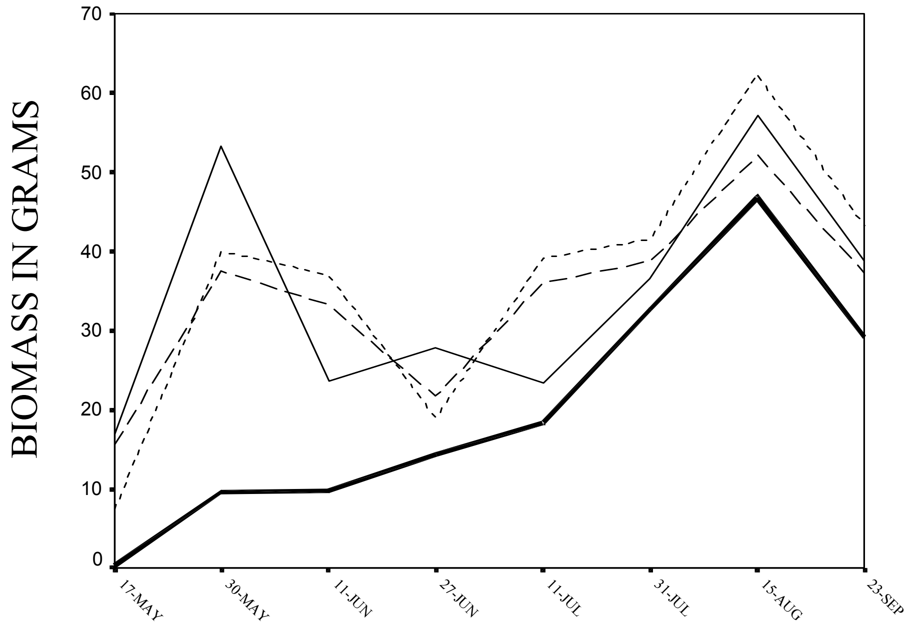

Figure 2: Dry weight of vegetation samples in grams, taken on HF and MLFE control and burn plots from May to September 1996. The HF site was burned in 1996 while the MLFE site had been burned the year before. ▬ = HF burn, - - - = HF control, — = MLFE burn, ---- = MLFE control.

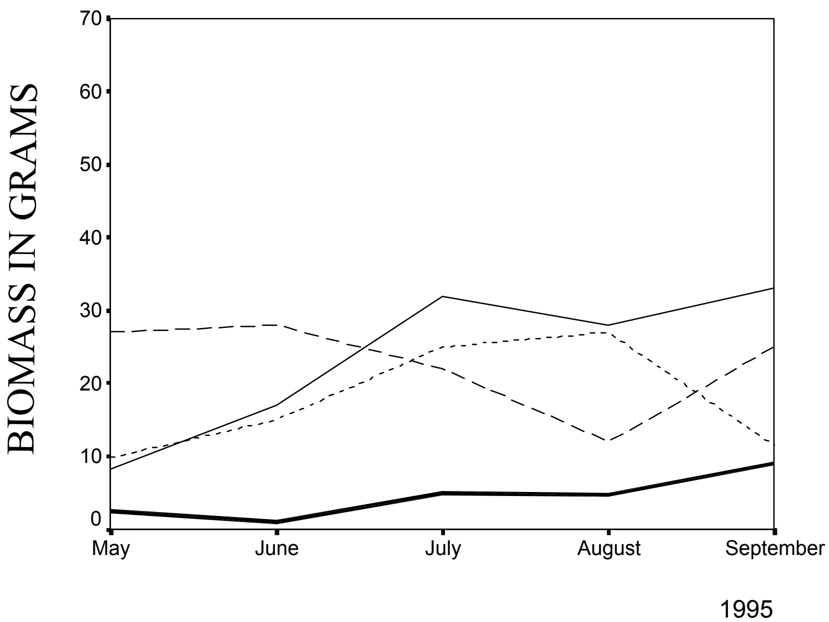

Figure 3: Dry weight in grams of dead and live vegetation taken on burned and control plots on the MLFE site from May to September 1995, the burn year. ▬ = dead vegetation on burn, – – – = dead vegetation on control. —— =live vegetation on burn, ········ = live vegetation on control.

Table 1. Bighorn sheep use of burned and control plots the year before, the year of burning and a year after in the Sheep River Wildlife Sanctuary, Alberta, 1994 to 1997. Chi-square and P-values refer to the comparison of control and burned plots each month. Same = each sheep group seen used both the burn and the controls plots during observations; not used = plot was not used by sheep; n. s. = no significant difference between the use of burns and controls. χ^2-values in brackets = use of burn higher than of controls. Normal χ^2 = use of control plots higher than of burns. Rows with locations, years and statistics in bold indicate year of burning.

LOCATION & YEAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER
MLFE 94	Not used	Not used	Not used	Not used	Not used	Not used
MLFE 95	**Not used**	**(χ^2 = 224) P<0.05**	**Not used**	**Not used**	**Not used**	**(χ^2 = 27) P<0.05**
MLFE 96	Not used	(χ^2 = 7) P<0.05	Not used	Not used	Not used	Not used
MLFE 97	Not used	Not used	Not used	Not used	(χ^2 = 20.4) P<0.05	(χ^2 = 18) P<0.05
HF 94	χ^2 = 0.65 n. s.	χ^2 = 1.1 n. s.	(χ^2 = 25) P<0.05	(χ^2 = 29) P<0.05	(χ^2 = 18) P<0.05	(χ^2 = 65) P<0.05
HF 95	(χ^2 = 72.7) P<0.05	(χ^2 = 214) P<0.05	(χ^2 = 26.5) P<0.05	(χ^2 = 8) P<0.05	χ^2 = 30.9 P<0.05	χ^2 = 5.2 P<0.05
HF 96	**(χ^2 = 54) P<0.05**	**(χ^2 = 5) P<0.05**	**(χ^2 = 7.2) P<0.05**	**(χ^2 = 31) P<0.05**	**(χ^2 = 284.1) P<0.05**	**(χ^2 = 56.5) P<0.05**
HF 97	(χ^2 = 79.1) P<0.05	(χ^2 = 84.1) P<0.05	(χ^2 = 11) P<0.05	(χ^2 = 54.01) P<0.05	(χ^2 = 192.2) P<0.05	(χ^2 = 6.1) P<0.05
WPE 94	Same	Same	Same	Same	Same	Same
WPE 95	Same	Same	Same	Same	Same	Same
WPE 96	Same	Same	Same	Same	Same	Same
WPE 97	**Same**	**(χ^2 = 20.3) P<0.05**	**(χ^2 = 23.3) P<0.05**	**(χ^2 = 53) P<0.05**	**Same**	**(χ^2 = 58) P<0.05**

In April and May of the burn years, on average 13% of all females (interquartile range = 24.9%; min. = 0%; max. = 70.8%) and 11.1% of all males (interquartile range = 20.8%; min. = 0%; max. = 62.2%) used the burns. In September on average 12.5% (interquartile range = 24.3%; min. = 2.0%; max. = 66.7%) of all females and 12.8% (interquartile range = 9.0%; min. = 0%; max. = 23.9%) of all males used the burns. There was no sex-biased use of the different burns in April, May or September (largest *Z*-value = -1.54, *P*= 0.12, *n*= 32 days, in spring on WPE).

There was no sexual difference in diet choice in 1995 or 1996 (*Z*= - 1.39, *P*= 0.17, *n*= 113 sheep). Fecal crude protein content was on average 14.1±4.2% for females and 15.7±5.3% for males. There was, however, a significant difference in overall fecal protein content between the years 1995 and 1996. In 1995, fecal protein content was much higher than in 1996 (*Z*= -6.90, *p*< 0.001, *n*= 113, Table 2).

In May when sheep use of the burns was greatest, they took on average 50±1 bites/min (*n*= 32 sheep) when grazing on the control and 56±2 bites/min (*n*= 20 sheep) when grazing on the burn plot. In autumn bite rates were similar on burn and control plots (respectively 41±1 bites/min and 43±6 bites/min, *n*= 20 sheep in each case, *F*= 2.72, *P*= 0.133). Over the entire summer, grazing sheep took more bites per minute on burns than on controls (*F*= 11.59, *P*< 0.01, *n*= 52 individuals). Surprisingly, in spring, males took more bites per minute than females on the burns (males: 59±1 bites/min, n = 22, females: 53±2 bites/min, n = 18; *Z*= - 2.51, *P*<0.05). The opposite was observed on controls, where females took more bites per minute than males (males: 49±1 bites/min, *n*= 38, females: 52±1 bites/min, *n*= 26; *Z*= - 2.16, *P*< 0.05).

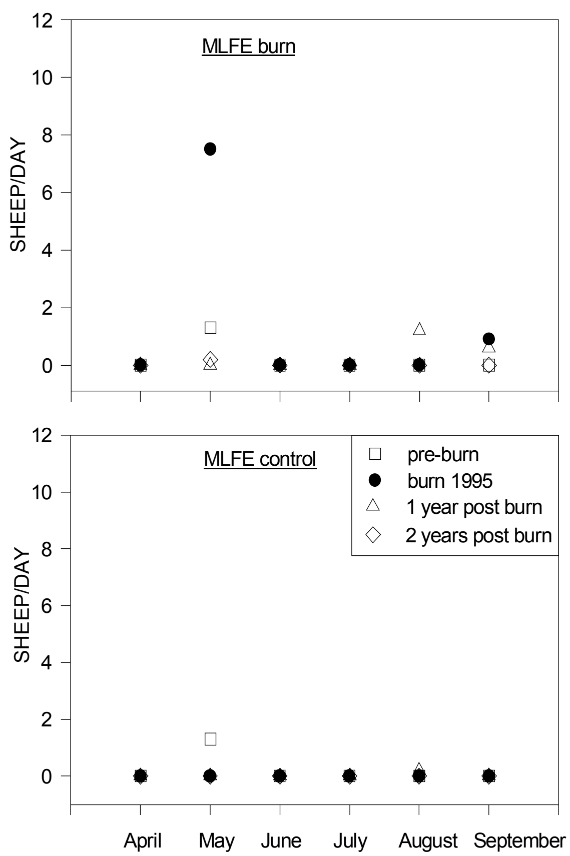

Figure 4: Observed average daily sheep use of the MLFE burn and control plots 1 year before, the year of the burn, 1 and 2 years after the burn (1994 – 1997). The MLFE site was burned on April 7, 1995.

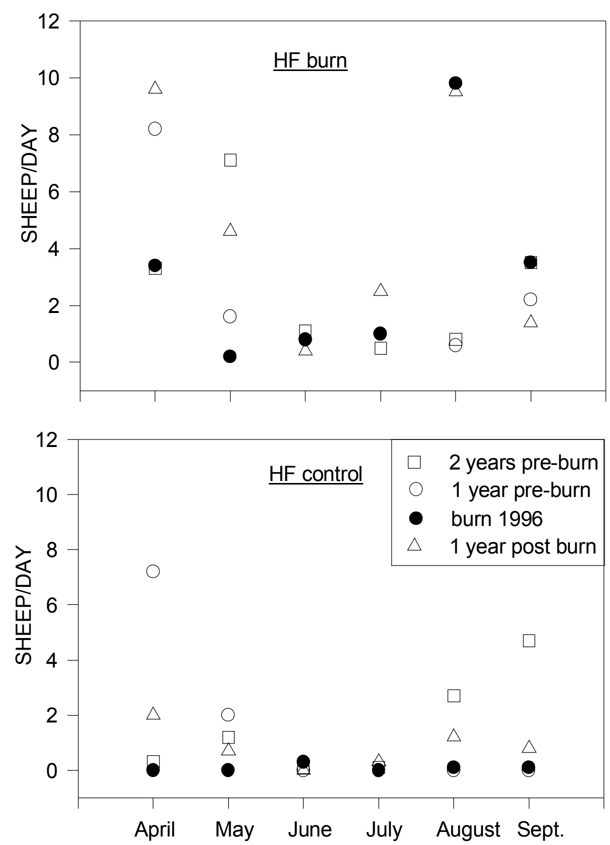

Figure 5: Observed average daily sheep use of the HF burn and control plots 2 and 1 years before, the year of the burn and 1 year after the burn (1994 – 1997). The HF site was burned on April 29, 1996.

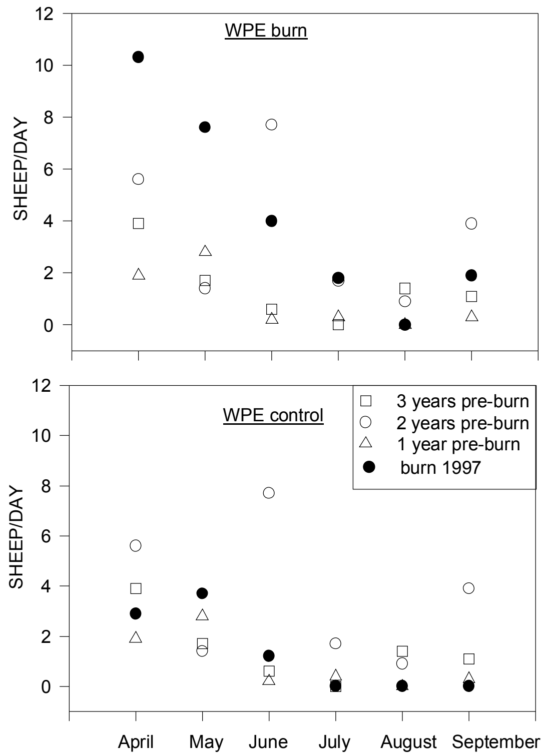

Figure 6: Observed average daily sheep use of the WP burn and control plots 3 to 1 years before and the year of the burn (1994 – 1997). The HF site was burned on April 6, 1997.

Table 2: Average percent of crude protein content found in feces of male and female bighorn sheep in spring 1995 and 1996, in the Sheep River Wildlife Sanctuary, Alberta, Canada. SD = Standard deviation of mean.

SEX & YEAR	% FECAL PROTEIN	SD	N	MEDIAN
Females 1995	18.34	2.98	20	18.86
Males 1995	20.24	3.97	20	20.25
Females 1996	11.51	2.34	33	11.48
Males 1996	13.39	4.27	40	12.47

DISCUSSION

From May to mid-June, the crude protein content of vegetation was much higher on burned than on control plots, but after mid-June burning had little effect on crude protein content. A seasonal effect of burning forage on crude protein content has also been reported by previous studies. Carlson et al. (1993) found that burning of Key woodland habitat in Florida increased the protein content of browse available for white-tailed deer (also called Key deer), especially in May, June, and July. McWhirter et al. (1992) reported that forage on burned grassland-brush sites had a significantly higher level of protein content than control sites each spring, and concluded that the benefits of burning lasted a minimum of 15 years, in terms of food availability and composition. Apparently, bighorn sheep living in their study area preferred burned plots to controls each year during spring (McWhirter et al. 1992). Hobbs and Spowart (1984) burned grass and brush communities and found that the effects of burning on forage crude protein lasted for at least 2 years, primarily due to a diet switch by animals grazing on the burn. In the Hobbs and Spowart (1984) study green grass was more abundant and nutritious (often exceeding 25% crude protein) on burned than control plots during winter, and the proportion of green grass eaten by an ungulate therefore increased the quality of its diet. In our study area there was no green grass available for ungulates during winter. Little annual variation exists in the timing of spring green-up due to the strongly seasonal climate. Furthermore, our study differs from Hobbs and Spowart (1984) in that we did not measure the protein content of separate plant species, rather we measured the overall protein content of all available vegetation for sheep. We could, therefore, demonstrate only a short-term increase in forage quality: forage protein 1 and 2 years after burning was not higher on burned than on control plots. Differences in sheep use of burned versus control sites over time also demonstrated the short-term benefits of grassland burns in northern climates. For example, sheep preferentially used the MLFE burn in spring and fall of the burn year, but not the year after.

It is not clear why burning had only a short-term effect on crude protein content or biomass production. Possibly, because especially grass biomass production in this area is generally high, dead vegetation had already accumulated by the first spring following the fire. A new layer of dead grass therefore could inhibit vegetation growth in the second year. Similarly, Seip and Bunnell (1985) found no difference in crude protein content of vegetation between burned and unburned Stone's sheep (*Ovis dalli stonei*) ranges during or after the year of a burn, although they stated that, in May, burned slopes provided more new forage for sheep than unburned slopes.

In our study, new forage on burns had a much higher crude protein content and was more accessible as it was not hidden by old growth. Many studies show a clear tendency for ungulates to prefer newly burned foraging plots over unburned ones (Hobbs and Spowart 1984, Shaw and Carter 1990, McWhirter et al. 1992, Coppedge and Shaw 1998). Preference for burns over controls is most likely due to 2 factors: the much higher level of crude protein usually found in new growth and the sometimes earlier availability (Hobbs and Spowart 1984) of new growth compared to controls. Burning therefore benefits sheep and other ungulates because it enhances forage quality.

Total biomass of forage available on burns, in our study, was not higher than on controls but new-growth forage on burns was more accessible than on controls. Not surprisingly, sheep preferred burn to control sites in all 3 years of our study. The MLFE site attracted bighorn sheep after burning until mid-June, which indicates that sheep selected this area because of the burn. Sheep did not usually use the MLFE burn or control sites during the years before or after the burn, again a clear indication that sheep were attracted to the site because of the burn. However, the WPE and HF sites were preferred grazing areas of sheep even before any burns were done: the HF burn site, for instance, was preferred over the HF control site even in pre-burn years. It was therefore difficult to determine whether sheep used the HF burn because they profited from higher quality forage or because they merely preferred the location, which coincided with the burn. Based on the sheep use on MLFE and WPE, which was highest in burn years, we conclude that sheep used the HF burn because of its higher protein content and not solely because it was a preferred site. Our burned plots were larger than the control plots, and burn plots may hence be expected to receive more sheep use than the control plots if sheep were distributed at random (see also Coppedge and Shaw 1998). If this was the case however, these differences in sheep use should have been seen every year. Instead, the WPE and MLFE burned plots were preferred only in the years of burning.

Sheep were using the high quality forage in May but less so in June, when the protein content was still much higher, mainly because females migrated to alpine areas after mid-May and rams moved east of the Wildlife Sanctuary. By the end of May in 1996, there were almost no females and sometimes only a few males left in the Sanctuary. Females moved back into the area in September, which explains the preferential use of burn plots in September and no use from June until September. Therefore it appears that burning affects site selection of bighorn sheep within a given seasonal range, but does not affect their seasonal migratory patterns. By September, crude protein content was similar on burned and control sites, but there was more live forage available on burns than on controls, because of dead grass accumulation on controls.

We expected that the increased biomass and quality of new vegetation would allow sheep to take more bites on burned plots than on controls. Bite rates were higher on the burns than on the controls in May but not in September. In another study (McWhirter et al. 1992), both bite rates and the time spent feeding on burns were significantly greater than on controls. Shaw and Carter (1990) reported that bison foraged at a disproportionately high rate on a grassland burn, but use declined gradually as summer progressed. The higher bite rate in May during our study is likely due to the fact that newly emerging forage in spring is short and faster to ingest and process than old vegetation. Sheep feeding on the burn would therefore be able to take more bites than on controls.

Contrary to our findings, Seip and Bunnell (1985) found no difference in bite rate of Dall's sheep feeding on burn or control patches. The number of bites an ungulate takes depends on several factors, such as bite and rumen size, plant structure and size, chewing and processing constraints, and availability of forage (Illius and Gordon 1992, 1993; Gross et al. 1995; Gordon et al. 1996). That Seip and Bunnell (1985) found no difference in bite rates on burns and controls could therefore be due to several factors. Sheep on burns and controls might have foraged at their maximum intake rate (if biomass in general was low on both sites). Total biomass availability could have been the same on both plots, which results in the same number of bites (independent of the proportion of dead versus live vegetation available per bite). Finally, sheep on burns might have taken more steps while foraging, decreasing bite rate.

Surprisingly, males took more bites per minute on the burns than females, while females took more bites than males on the controls. Smaller individuals may take more bites to compensate for their smaller incisor bar size, so it is not really surprising that the smaller bighorn sheep females took more bites than the larger males (Gross et al. 1995). In late April and early May, new growth on burns was just beginning to emerge. The relatively short size of the forage could therefore explain why males took more bites than females. On normal-height vegetation, large males, with their larger mouths, have a relatively bigger intake of food than females but this may be more difficult to achieve at very short forage heights. They therefore may need to increase their bite rate to achieve the same total intake as on taller vegetation.

Contrary to our predictions, there was no sex difference in burn use, which suggests that both males and females benefited from higher quality forage in spring. Furthermore, there was no sexual difference in diet choice, reflected by fecal crude protein content of the forage. Although some studies have supported the hypothesis that females opt for higher quality forage than males, others found no difference or the reverse (Main et al. 1996). To our knowledge, only Coppedge and Shaw (1998) examined the effects of sex on use of burns. The authors found that bull groups showed less attraction to burned areas than female groups, supporting the hypothesis that the smaller females should opt for high quality forage while the larger males do no not need to do so (Main et al. 1996). Our results indicate that there is no sexual difference in diet choice in bighorn sheep, although the larger males had a slightly higher fecal protein content than the smaller females. If forage is of higher quality, or is accessible earlier in the season, males may select these areas, and hence recover earlier from energy loss (due to the winter and the rut), and therefore increase their body condition and chance of survival. Gravid females will have a higher protein supply to satisfy the energy demands of their last month of gestation. Both males and females therefore can profit from late winter/early spring burning of grassland.

As shown by this study, there is a direct link between burning grassland patches and the increase in forage quality and sheep use of such patches, at least for the year of the burn. Annual grass burns should be done early in the year (preferably between February and mid-April), when snow in the forests can minimise the danger of fire escaping the prescribed boundaries. Burning grasslands could then be used as a useful, and sometimes inexpensive management tool to increase bighorn range quality in key areas.

Increasing range quality would likely lead to population growth or to sheep in better body condition. Prescribed burning of grasslands could, therefore, not only profit bighorn sheep but likely other grazing ungulates (mainly elk, white-tailed and mule deer) sharing the same habitat. The burns should ideally be planned and conducted to closely match the known natural fire rotation period for the particular ecosystem where the bighorn sheep or other ungulates under consideration live. In taking these rotation periods into account, vegetation type conversions or the loss of local plant species due to too frequent burning can be avoided.

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