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FORAGING BEHAVIOR AND VEGETATION RESPONSES TO PRESCRIBED BURNING ON BIGHORN SHEEP WINTER RANGE

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Abstract: Prescribed burning has been used as a habitat management tool on the South Fork of the Shoshone River, near Cody, Wyoming for over 15 years. The primary emphasis has been to improve foraging conditions for wintering Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*). In 1986 a study was initiated to determine the effect of prescribed fire on winter range vegetation, sheep diet quality, and foraging behavior. Burning increased herbaceous plant production and removed shrubs that obstructed visibility. Diet quality and foraging efficiency of wintering sheep were greater on burned vegetation types when compared to sagebrush and juniper dominated sites. Radio-collared sheep selected burned areas as foraging habitats in spring. Prescribed burning may increase nutrient density, allowing sheep to obtain higher quality diets and higher nutrient intake rates. Implications of these findings to bighorn sheep habitat ecology management are discussed.

Bighorn sheep populations in the western United States have declined markedly in both distribution and density since the early part of this century (Buechner 1960). Transplants of sheep into their former ranges and supplements to stagnated populations are often attempted to reverse the decline. In Wyoming, such efforts have been relatively unsuccessful (Smith and Butler 1988). Failure of reintroductions and attempts to rejuvenate herds can be attributed primarily to altered habitat conditions. Loss of open foraging areas and traditional migration routes to conifer and shrub encroachment has been suggested as being responsible for the loss of many sheep populations (Wakelyn 1987).

Fire suppression and lack of habitat management have been

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identified as major factors responsible for the degradation and loss of suitable bighorn sheep habitat (Wakelyn 1987). Many bighorn sheep winter ranges exist within shrub-grass vegetation communities, where fire plays an important role in the maintenance of ecological processes (Wright and Bailey 1982). Fire increases herbaceous plant production, eliminates competing shrubs and trees, facilitates nutrient recycling, and encourages use by herbivores. Following settlement of the west, fires were suppressed and livestock grazing increased. These changes altered the structure and productivity of big game habitats (Houston 1973, Gruell 1980, Gruell 1986).

We examined the effect of prescribed fire upon winter range vegetation and determined the effect of vegetation changes upon bighorn sheep foraging behavior. Specific objectives were to determine:

1. Herbaceous forage production responses to prescribed fire.

2. Shrub and tree response to fire.

3. Diet quality of wintering sheep on burned and unburned vegetation types.

4. Foraging efficiency of wintering sheep in burned and unburned vegetation types.

Bighorn sheep on the South Fork of the Shoshone River are habituated to humans and can be approached closely without interrupting normal feeding behavior. Such habituation allowed us to collect detailed diet quality and foraging behavior data.

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STUDY AREA

The South Fork study area is located approximately 64 km (40 mi) southwest of Cody, Wyoming (Fig. 1), and lies within the Shoshone National Forest. Within this geographical area, we sampled a narrow strip of sheep winter range that rarely exceeded 1.6 km (1 mi) in width and covered approximately 1,066 ha (2,618 ac). The boundaries of the study area included Ishawooa Creek, Cabin Creek, the South Fork of the Shoshone River, and Ishawooa Mesa. Although the winter range is primarily on Forest Service lands, several parcels of private land intermixed with the federal holdings are used extensively by sheep. Although quite variable, sheep numbers on the winter range averaged 275 to 300 animals.

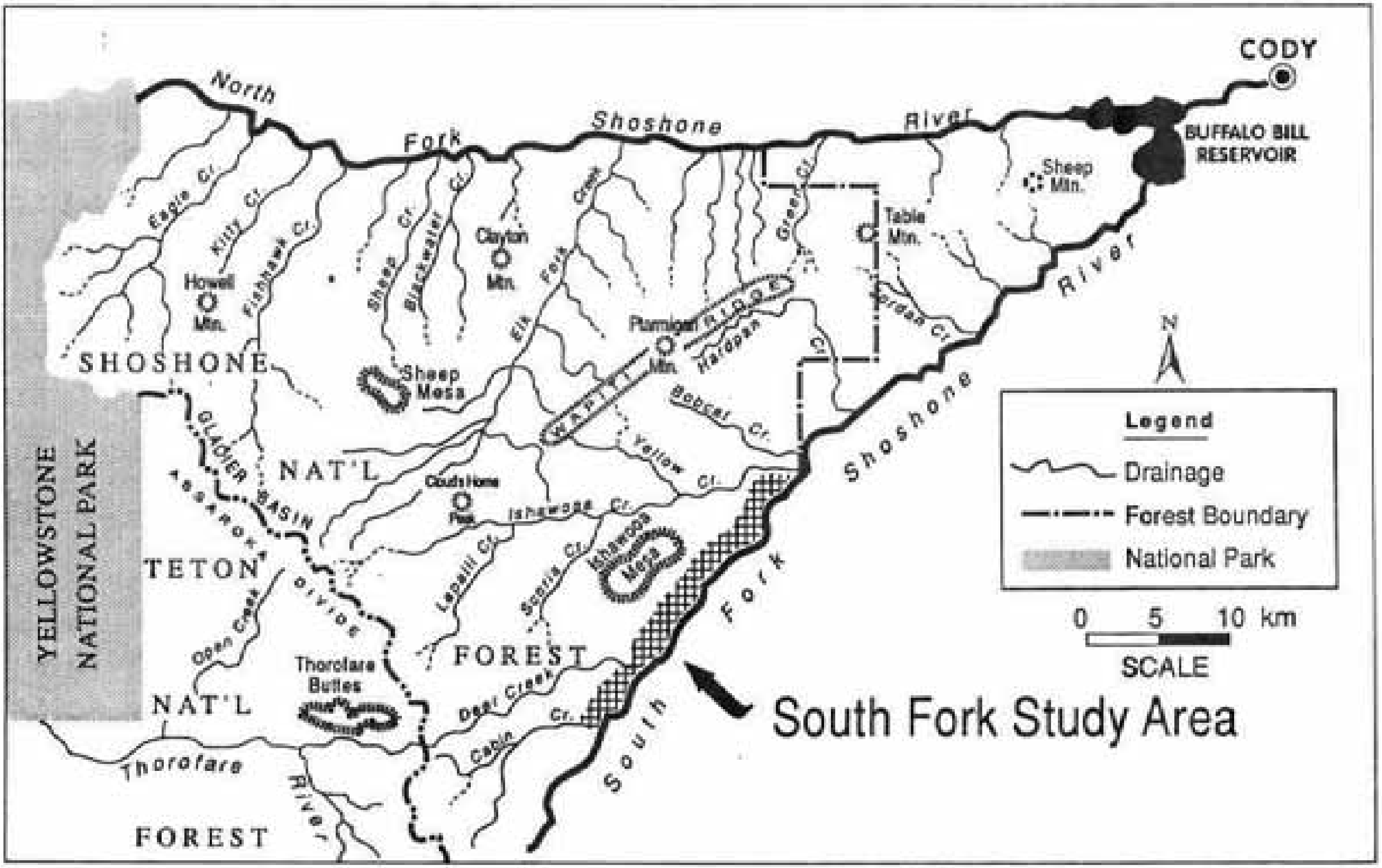

Fig. 1. Location of South Fork Study Area, northwestern Wyoming.

Topography within the study area consists of massive cliffs, steep hillsides, and gently sloping sagebrush grasslands with little or no transitional areas. The majority of the winter range is composed of southeast-facing, sagebrush-covered slopes that vary in elevation from 1,891 m (6,200 ft) to approximately 2,135 m (7,000 ft). These sagebrush grasslands are characterized by foothills and alluvial fans with moderate to deep soils varying in texture from cobbly sand loam or loamy sand to gravelly sand or clay loam (U.S. Dep. Agric. 1986).

Although a variety of vegetation communities exist on the South Fork of the Shoshone River, for purposes of this study 3 general vegetation types were delineated based on structural and compositional characteristics: sagebrush-grassland (SG), sagebrush-grass-juniper (SGJ), and burn (BURN).

The SG type consists primarily of Wyoming big sagebrush (Artemisia tridentata wyomingensis) and basin big sagebrush (Artemisia tridentata tridentata) with an understory of various grasses including bluebunch wheatgrass (Agropyron spicatum), needle-and-thread (Stipa comata), prairie junegrass (Koeleria cristata), and Sandberg bluegrass (Poa secunda). Most forbs that occur on the study area are essentially unavailable to wintering sheep due to desiccation and senescence.

The SGJ type is similar to the SG type, except for the addition of Rocky Mountain juniper (Juniperus scopulorum), creeping juniper (Juniperus horizontalis), and an occasional limber pine (Pinus flexilis). Herbaceous vegetation production in SGJ types is scant due to competition for light and nutrients from the juniper and dense sagebrush components.

Four prescribed burns (BURN) were sampled, ranging from 3 to 14 years in age and varying in size from 2.4 ha (6 ac) to 8.1 ha (20 ac). They encompassed both spring and fall burns, and occurred in both SG and SGJ vegetation types. Species composition of the burned areas included many of the same species as unburned areas, except for the addition of kingspike fescue (Leucopoa kingii), green needlegrass (Stipa viridula), rubber rabbitbrush (Chrysothamnus nauseosus), and Douglas rabbitbrush (C. viscidiflorus). The most noticeable feature within the BURN vegetation type, however, was the significant reduction in shrubs and trees.

METHODS

Vegetation Sampling

Permanent transects were established to monitor vegetation responses. The four burned sites were sampled using four 25-m transects each. An unburned control area of similar elevation, slope, and aspect was sampled in the same manner at each BURN site. Fifteen 0.1 m^2 quadrats were sampled along each transect for percent canopy cover and frequency of herbaceous species (Daubenmire 1959). Herbaceous production was estimated using a double-sampling technique (Wilm et al. 1944).

Shrub cover was sampled along each transect with a point-intercept technique (Mueller-Dombois and Ellenberg 1974). Presence or absence of shrubs was recorded at each of 50 points along the transect. Maximum height of each shrub was also measured.

Diet Quality

Simulated diets of bighorn sheep were collected by following randomly selected adult ewes and hand-plucking a 50-100 g sample that mimicked plants and plant parts that were observed to be eaten. Samples were collected every 2 weeks in each of the 3 vegetation types.

Simulated diets were oven dried at 65 C for 24 hrs, ground in a Wiley mill to pass through a 1mm mesh screen, and analyzed for crude protein. Crude protein content (Kjeldahl nitrogen X 6.25) was determined using methods described by the Association of Official Agricultural Chemists (1965). Data were averaged for winter (Nov-Feb) and spring (Mar-May) periods.

Foraging Habitat Selection

Selection of foraging habitats was determined by comparing use with availability of the various vegetation types. Use of vegetation types was obtained from weekly visual relocations of 13 radio-collared sheep. Availability was estimated from aerial photos and ground-truthed vegetation maps.

Foraging Behavior

Information collected on foraging behavior included bite rates and foraging time. Bite rates were obtained by recording the time required for an individual ewe to obtain 100 bites. The stopwatch was running only while the animal's head was down biting or searching for forage. When the animal's head was lifted, the clock was stopped. A bite was defined as a distinctive jerking motion of the head while the animal was feeding. Time required per 100 bites was converted to the number of bites/minute. Bite rate estimates were obtained monthly in each vegetation type ($\underline{n}$ = 594). This sampling technique was designed to be an index to the time required to search for and ingest forage.

Foraging time was determined from 10-minute activity profiles conducted in each vegetation type ($\underline{n}$ = 581). The behavior of an adult ewe was recorded each minute (instantaneous sample). Behaviors recognized were feeding, walking, alert, resting, running, and courtship. Data were summarized by vegetation type to arrive at an estimate of minutes spent feeding/10 minutes. Information gathered concurrently with activity profiles included date, time, location, aspect, slope, elevation, snow depth, group size, distance from escape terrain, and distance travelled during the 10-minute sample. Foraging behavior data were also averaged over winter and spring periods.

Data Analysis

One-way analysis of variance (ANOVA) was used to test for differences in vegetation between burned areas and their respective controls (Zar 1984). One-way ANOVA was also used to examine differences in diet quality and foraging behavior among vegetation types. If the ANOVA was significant ($\underline{P} < 0.05$), least significant difference (LSD) multiple range tests were performed to determine the significant differences among the various vegetation types.

Foraging habitat selection was determined using Chi-square analyses, which tests the hypothesis that all vegetation types are used in proportion to their availability (Neu et al. 1974). Application of Bonferroni confidence intervals to situations where the null hypothesis has been rejected allows identification of selected habitats, avoided habitats, and those used in relation to their availability (Byers et al. 1984). Selection behavior of sheep was analyzed for winter and spring periods separately.

Data reported are from the 1988-1989 winter. This winter followed a drought period responsible for extensive fires in the Greater Yellowstone Ecosystem (Romme and Despain 1989).

RESULTS

Vegetation Response

Herbaceous production was consistently greater on burned areas compared to controls (Fig. 2). However, significant differences were found on only 2 sites. Shrub cover was significantly less on burned areas compared to controls for all sites. (Fig 3). Shrub height on burned areas was less than that of nearby unburned control areas (Fig. 4). Significant differences were detected on 2 of the 4 sites.

Diet Quality

Crude protein content of simulated sheep diets from BURN vegetation types was consistently greater than diets obtained from SG and SGJ types. However, this relationship was significant only in spring (Fig. 5).

Foraging Behavior

Bite rates of sheep feeding in BURN vegetation types were significantly greater than rates obtained by sheep feeding in SG and SGJ communities with one exception. Although greater, bite rates in the BURN did not differ significantly from those in the SG type in winter (Fig. 6). Time spent feeding was significantly greater for sheep feeding in BURN vegetation types compared to those feeding in SG and SGJ types in both winter and spring (Fig. 7).

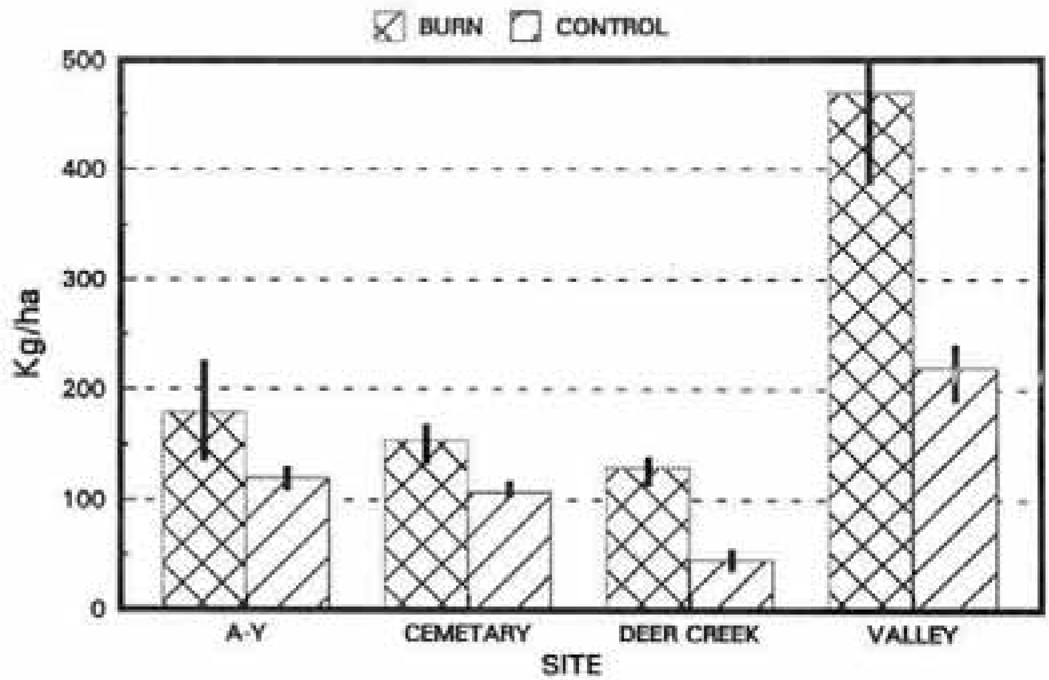

Fig. 2. Herbaceous forage production (± S.E.) on burned and unburned vegetation types, South Fork Shoshone River, 1988.

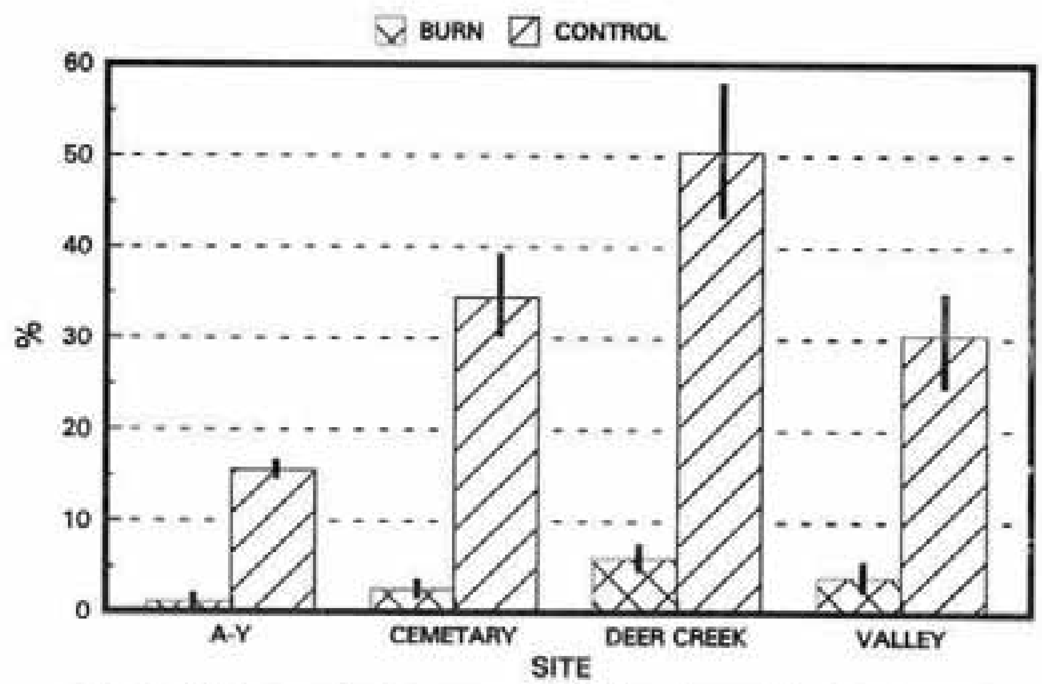

Fig. 3. Average shrub cover (± S.E.) on burned and unburned vegetation types, South Fork Shoshone River, 1988.

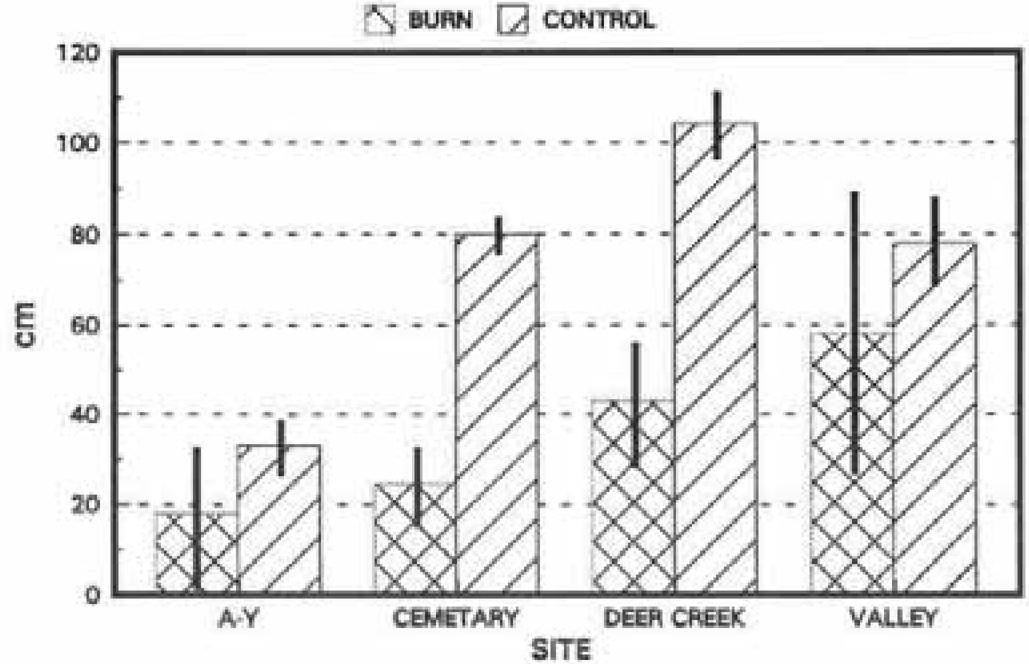

Fig. 4. Average shrub height (± S.E.) on burned and unburned vegetation types, South Fork Shoshone River, 1988.

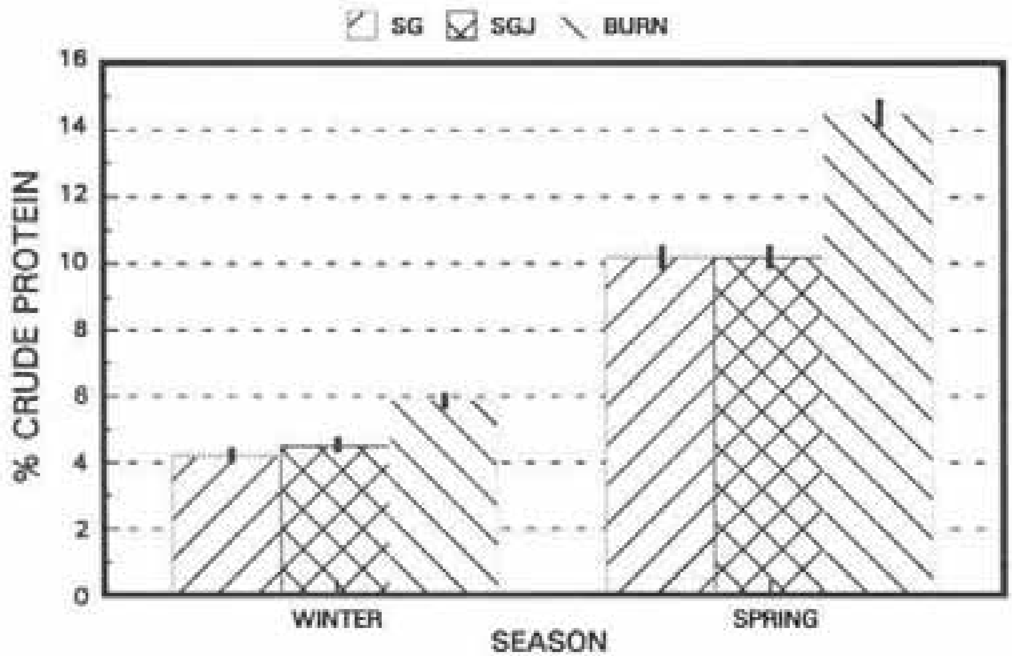

Fig. 5. Crude protein content (± S.E.) of simulated bighorn sheep diets, South Fork Shoshone River, 1988-89. SG = Sagebrush/Grass, SGJ = Sagebrush/Grass/Juniper.

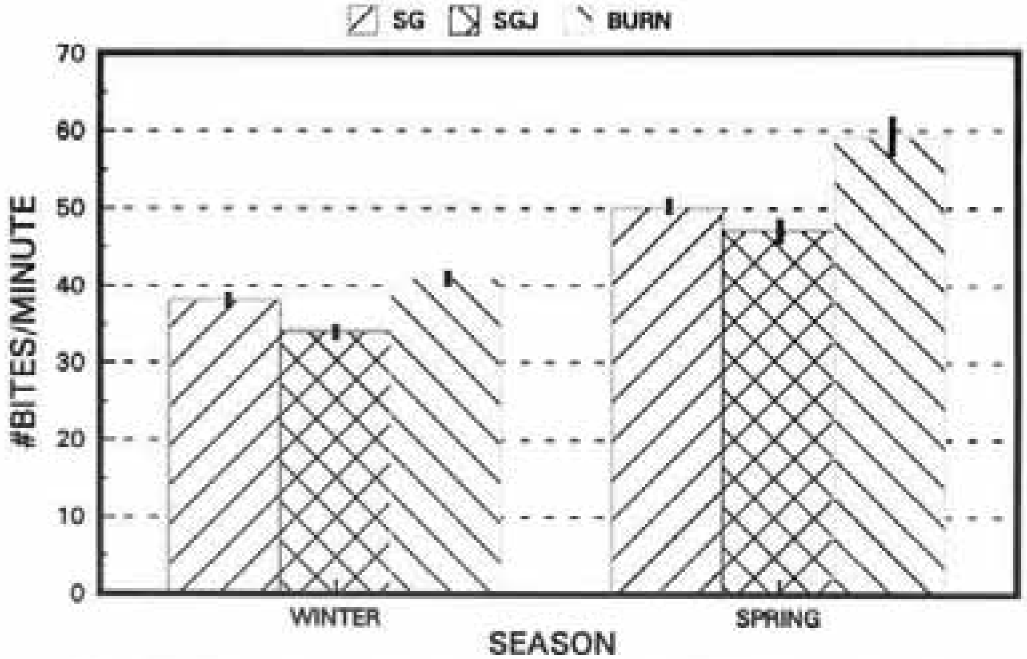

Fig. 6. Bite rates of bighorn sheep (± S.E.) in burned and unburned vegetation types, South Fork Shoshone River, 1988-89. SG = Sagebrush/Grass, SGJ = Sagebrush/Grass/Juniper

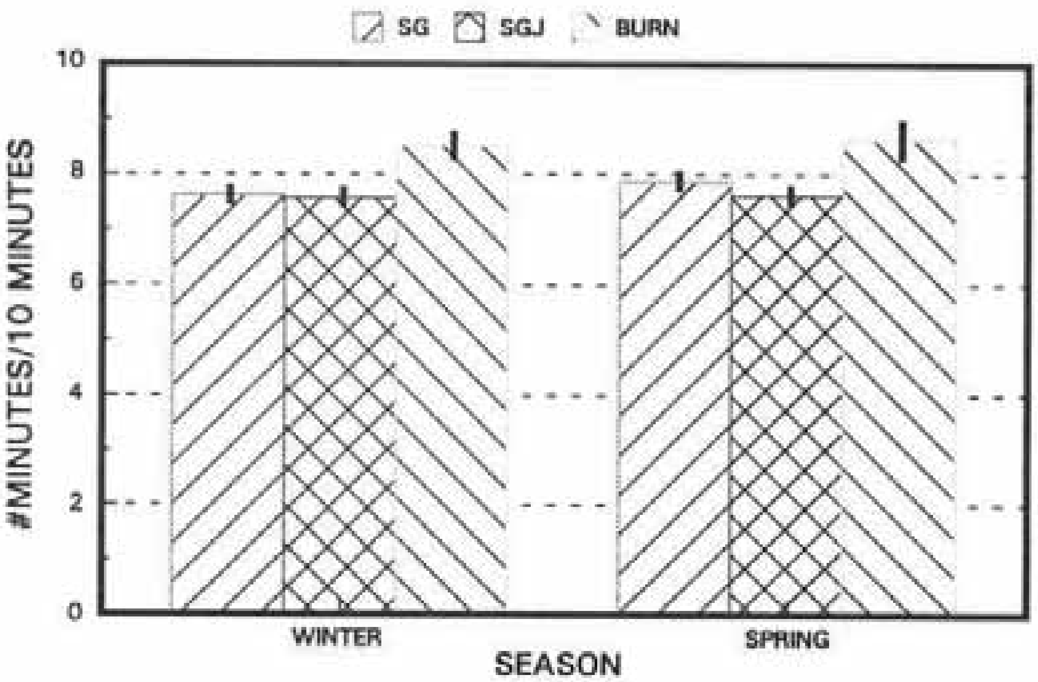

Fig. 7. Foraging time of bighorn sheep (± S.E.) in burned and unburned vegetation types, South Fork Shoshone River, 1988-89. SG = Sagebrush/Grass, SGJ = Sagebrush/Grass/Juniper

Foraging Habitat Selection

Winter habitat selection analysis revealed that SG vegetation types were used less than would be expected based on availability. Although selection for BURN types approached significance, both BURN and SGJ types were used in relation to their availability (Table 1). Selection of foraging habitats in spring revealed a preference for BURN vegetation types, while use of the SG was less than expected and SGJ types were used in proportion to availability.

DISCUSSION

Observed vegetation responses to burning have a profound effect upon the foraging ecology of bighorn sheep. Subtle increases in nutrient content of forages in burned areas have been documented (Willmset al. 1981, Harris and Covington 1983, Cook et al. 1990).

Table 1. Foraging habitat selection by bighorn sheep, South Fork Shoshone River, Wyoming, 1988-89.

Vegetation type	Proportion expected	Proportion observed	95% C.I.	Selection behavior
WINTER (*n* = 103)				
SG[a]	0.694	0.417	0.296 - 0.539	-[d]
SGJ[b]	0.195	0.262	0.154 - 0.370	NS[e]
BURN[c]	0.024	0.087	0.018 - 0.157	NS
SPRING (*n* = 121)				
SG	0.694	0.322	0.216 - 0.428	-
SGJ	0.195	0.281	0.179 - 0.383	NS
BURN	0.024	0.174	0.088 - 0.260	+[f]

[a] Sagebrush-grass vegetation type
[b] Sagebrush-grass-juniper vegetation type
[c] Burn vegetation type
[d] Use of vegetation type less than expected
[e] Use of vegetation type in relation to availability
[f] Use of vegetation type greater than expected

Although such increases may appear to be slight, when coupled with increased forage production, nutrient density is increased. Increased nutrient density should allow an animal to obtain a higher quality diet. Our data support this contention, as sheep diet quality was greatest in BURN vegetation types. The combination of increased forage quality and quantity may allow an animal to be more selective,thus optimizing diet quality.

Observed vegetative responses to prescribed fire also had a large effect on the foraging behavior of wintering sheep. Higher bite rates were observed from sheep feeding during foraging bouts in burned areas and sheep spent more time actually feeding in burned areas compared to unburned communities. This can be explained by the reduction in shrub cover and shrub height as a result of burning. The removal of the shrub canopy allows sheep to forage more efficiently. Less time is spent in search of potential bites as a result of increased forage densities, and time spent feeding increases as a result of the increased visibility resulting from shrub removal. In addition, sheep preferred these open areas as foraging habitats.

Many researchers have examined total daily feeding time in response to vegetation characteristics, pasture conditions, and animal foraging behavior responses (Allden and Whittaker 1970, Seip and Bunnell 1985, Hudson and Frank 1987), but few have looked at the percentage of time spent feeding in various vegetation types on an instantaneous basis. Studies that have been conducted to address this question have found that visibility and group sizes are very important in determining the amount of time spent feeding in different habitats (Berger 1978, Alados 1985, Risenhoover and Bailey 1985, Warrick and Krausman 1987).

Visibility is a very important aspect of sheep foraging ecology. This is primarily due to the predator avoidance response of bighorn sheep. Sheep rely almost exclusively on eyesight to detect predators (McCann 1956, Geist 1971). When vision is occluded, the ability to detect predators is reduced. Therefore, when sheep feed in areas where visibility is limited, a substantial amount of time is spent watching for predators or watching for visual cues from cohorts (Risenhoover and Bailey 1985). Such time spent in alert behaviors can seriously reduce the amount of time actually spent ingesting forage. Data from the 10-minute activity profiles revealed that sheep did spend significantly more time in alert postures when feeding in SG and SGJ vegetation types when compared to BURN vegetation types. This is, as stated above, attributable to decreased visibility in SG and SGJ types. When feeding in BURN types, sheep could scan the environment for predators while their head was down. Thus, foraging time need not be spent surveying for predators.

With increased diet quality of sheep feeding in BURN vegetation types, and increased foraging efficiency (bite rates, time spent feeding), one would expect that nutrient intake rates could be enhanced by prescribed burning. Prescribed burning on the South Fork of the Shoshone River has been shown to increase forage production, visibility, diet quality, and foraging efficiency. Together, these factors represent the creation of high quality habitats for bighorn sheep.

MANAGEMENT RECOMMENDATIONS

By nature, bighorn sheep are very sensitive to habitat loss or alteration. Fire suppression and lack of habitat management have been identified as factors which have caused the degredation and loss of many suitable bighorn ranges (Wakelyn 1987). Efforts must be made to actively manage sheep habitat or risk further losses. Although these recommendations are specific for the South Fork of the Shoshone River, they may have broad application for burning on bighorn sheep winter ranges. Recommendations are:

1. Implement prescribed burns when and where applicable. Although dominated by low potential range sites, there are areas on the winter range that will respond favorably to fire. Even if herbaceous vegetation response is not optimal, the creation of open foraging areas without obstructing shrubs and trees, will benefit sheep through increased foraging efficiency. Areas that might not burn in average years may have sufficient fuels following high forage production years. Efforts should be made to treat pre-determined areas when these circumstances arise.

2. As stated by Smith (1988), prescribed burns should be large enough, to attract sheep. This would also reduce the potential for over utilization of recent burns. It appears from this work that the benefits of burning last a minimum of 15 years. A rotational treatment schedule in which 1/15 - 1/20 of the "burnable" winter range is treated each year might be optimal. This would create a diversity of seral types, providing high quality foraging areas for sheep while providing for habitat requirements for other wintering ungulates as well.

3. As emphasized in many prescribed burn plans, resting the burn from livestock grazing the first growing season after the fire is a must. One of the burns on the South Fork was grazed the season following treatment. This resulted in removal of preferred grass species and establishment of cheatgrass and other undesireable annuals. If fine fuel accumulations are necessary in order for a project to succeed, deferment of grazing prior to burning should be considered.

4. Treatments should be applied in a manner that creates a mosaic of vegetation types. Because large concentrations of other big game species exist on the South Fork, habitat improvements should not be directed solely at bighorn sheep. Consideration should be given to other species, especially mule deer (Odocoileus hemionus), when vegetation manipulation techniques involve the removal of shrubs. In addition, Goodson et al. (1991) has shown that sheep forage in dense shrub communities when snow precludes feeding in open vegetation types. This behavior was not observed on the South Fork of the Shoshone River, but could be explained by the very mild winters during which data were collected.

5. Although not applicable to most areas in the high security, alpine summer ranges of the Absaroka Mountains, prescribed burning may provide foraging efficiency benefits to other sheep herds where spring-summer-fall ranges are threatened by shrub-conifer encroachment. This would be particularly useful to the semi-low elevation sheep herds of south-central Wyoming.

6. Numbers of sheep utilizing the South Fork winter range seems to be increasing and may be approaching ecological carrying capacity. Due to heavy use of hay meadows, private landowners play a significant role in the determination of acceptable/allowable numbers of sheep. In addition to unacceptable levels of use in the private meadows, native vegetation types might be adversely affected. Repeated overuse could degrade native communities and increase dependence of sheep upon the meadows. This situation should be addressed promptly. Transplant options, as well as female harvest, should be investigated as potential methods of herd reduction. Harvest objectives for other big game species should be achieved as well in order to reduce the potential for direct and indirect competition for space and forage.

LITERATURE CITED

Alados, C. 1985. An analysis of vigilance in the Spanish ibex (Capra pyrenaica). Z. Tierpyschol. 68:58-64.

Allden, W.G., and I.A. McD. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. Aust. J. Agric. Res. 21:755-766.

Association of Official Agricultural Chemists. 1965. Official Methods of Analysis, Tenth ed. Washington, D.C. 957pp.

Berger, J. 1978. Group size, foraging, and antipredator ploys: An analysis of bighorn sheep decisions. Behav. Ecol. Sociobiol. 4:91-99.

Buechner, H.K. 1960. The bighorn sheep in the United States, its past, present, and future. Wildl. Monogr. No. 4, 174pp.

Byers, C.R., R.K. Steinhorst, and P.R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Cook, J.G., E.B. Arnett, L.L. Irwin, and F.G. Lindzey. 1990. Mountain sheep response to burning in southcentral Wyoming. Dep. Zoology and Physiology, Univ. of Wyoming, Laramie. 84pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-64.

Geist, V. 1971. Mountain sheep: A study in behavior and evolution. The Univ. of Chicago Press, Chicago, Ill. 383pp.

Goodson, N.J., D.R. Stevens, and J.A. Bailey. 1991. Effects of snow on foraging ecology and nutrition of bighorn sheep. J. Wildl. Manage. 55:214-222.

Gruell, G.E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Vol II - Changes and causes, management implications. U.S. Dep. Agric. For. Serv. Pap. INT - 252. 35pp.

Gruell, G.E. 1986. Post 1900 mule deer eruptions in the intermountain west; principal cause and influences. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. INT - 206. 37pp.

Harris, G.R., and W.W. Covington. 1983. The effect of a prescribed fire on nutrient concentration and standing crop of understory vegetation in ponderosa pine. Can. J. For. Res. 13:501-507.

Houston, D.B. 1973. Wildfires in northern Yellowstone National Park. Ecology. 54:1111-1117.

Hudson, R.J., and S. Frank. 1987. Foraging ecology of bison in aspen and boreal habitats. J. Range Manage. 40:71-75.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John C. Wiley & Sons, New York, N.Y. 547pp.

McCann, L.J. 1966. Ecology of the mountain sheep. Am. Midl. Nat. 56:297-324.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Risenhoover, K.L., and J.A. Bailey. 1985. Foraging ecology of mountain sheep: Implications for habitat management. J. Wildl. Manage. 49:797-804.

Romme, W.H., and D.G. Despain. 1989. The Yellowstone Fires. Sci. Am. 261:37-46.

Seip, D.R., and F.L. Bunnell. 1985. Foraging behavior and food habits of Stone's sheep. Can. J. Zool. 63:1638-1646.

Smith, S.G. 1988. Diet quality of wintering bighorn sheep on burned and unburned vegetation types: South Fork Shoshone River, Wyoming. M.S. Thesis, Univ. of Wyoming, Laramie. 95pp.

Smith, S.G. and G. Butler. 1988. Review of transplanted bighorn sheep herds in Wyoming. Wyoming Game and Fish Dep., Cheyenne. 21pp.

U.S. Department of Agriculture. 1986. Land and resource management plan: Shoshone National Forest, Cody, Wyoming. 250pp. and 10 appendices.

Wakelyn, L.A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. J. Wildl. Manage. 51:904-912.

Warrick, G.D., and P.R. Krausman. 1987. Foraging behavior of female mountain sheep in western Arizona. J. Wildl. Manage. 51:99-104.

Willms, W., A.W. Bailey, A. McLean, and C. Kalnin. 1981. Effects of fall clipping or burning on the distribution of chemical constituents in bluebunch wheatgrass in spring. J. Range Manage. 34:267-269.

Wilm, H.G., D.F. Costello, and G.E. Klippe. 1944. Estimating forage yield by the double sampling method. J. Am. Soc. Agron. 36:194-203.

Wright, H.A., and A.W. Bailey. 1982. Fire ecology, United States and southern Canada. John Wiley and Sons, New York, N.Y. 501pp.

Zar, J.H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood, N.J. 620pp.