6-1-1989

Forage Quality in Burned and Unburned Aspen Communities

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RESEARCH SUMMARY

We assessed the effects of fire on the quality of herbaceous and browse forage for elk (*Cervus elaphus*) and domestic sheep in the aspen (*Populus tremuloides*) forest type. Selected forage species were sampled on burned and adjacent unburned areas during the summers of the first and second years after autumn prescribed burning of three sites in southeastern Idaho. These samples were analyzed for in vitro dry matter digestibility (IVDMD), crude protein, calcium, and phosphorus. This aspen type has a highly nutritious understory irrespective of burning. We found additional improvement in forage quality as a result of prescribed burning. In the middle of the first summer, aspen on the burned areas had higher crude protein and phosphorus contents, higher elk IVDMD, lower calcium contents, and lower calcium/phosphorus ratios than aspen had on the unburned areas. A month later, only crude protein levels of aspen remained higher on the burns. All of the shrubs analyzed in the first summer had higher crude protein levels on the burned areas. A year later, none of the shrubs or forbs on the burns had better forage quality than those under nearby unburned aspen. Pinegrass (*Calamagrostis rubescens*) on the burned areas in the second summer had more robust growth but lower IVDMD and crude protein values, likely due to more extensive flowering and seed production, than did pinegrass on unburned areas. Prescribed burning on these sites changed species composition from dense shrub motts to more palatable and nutritious forbs than were found on the unburned areas.

Cover illustration: Aspen regeneration amidst lush grass and forb production 2 years after prescribed fire in the Bridger-Teton National Forest, WY.

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INTRODUCTION

There are more than 7 million acres (3 million hectares) of aspen (*Populus tremuloides* Michx.) in the West. Very likely fire has played an important role in maintaining most of this aspen. On the majority of sites, aspen is even-aged and is seral to conifers. A stand-killing fire at any time prior to the disappearance of aspen from a conifer stand often will result in a stand of vigorous aspen suckers (Jones and DeByle 1985). Many decades of fire control in the West have resulted in mature to old aspen stands on most sites (Shepperd 1981). Wildfire in the aspen forest today is an unusual event (DeByle and others 1987).

Silviculturists and wildlife biologists alike generally feel that a predominance of mature to old stands of aspen is not desirable for either the forest or wildlife. Hence, with increasing frequency in the West, land managers are taking steps to rejuvenate aspen on public lands. These steps include the use of prescribed fire to kill conifers that are taking over aspen sites and to kill the existent aspen trees for the purpose of stimulating growth of vigorous stands of young even-aged aspen root suckers (fig. 1). A multiaged mosaic of even-aged aspen stands eventually should be found in western forests.

Figure 1—A helitorch being used to burn mature and decadent aspen in the Bridger-Teton National Forest.

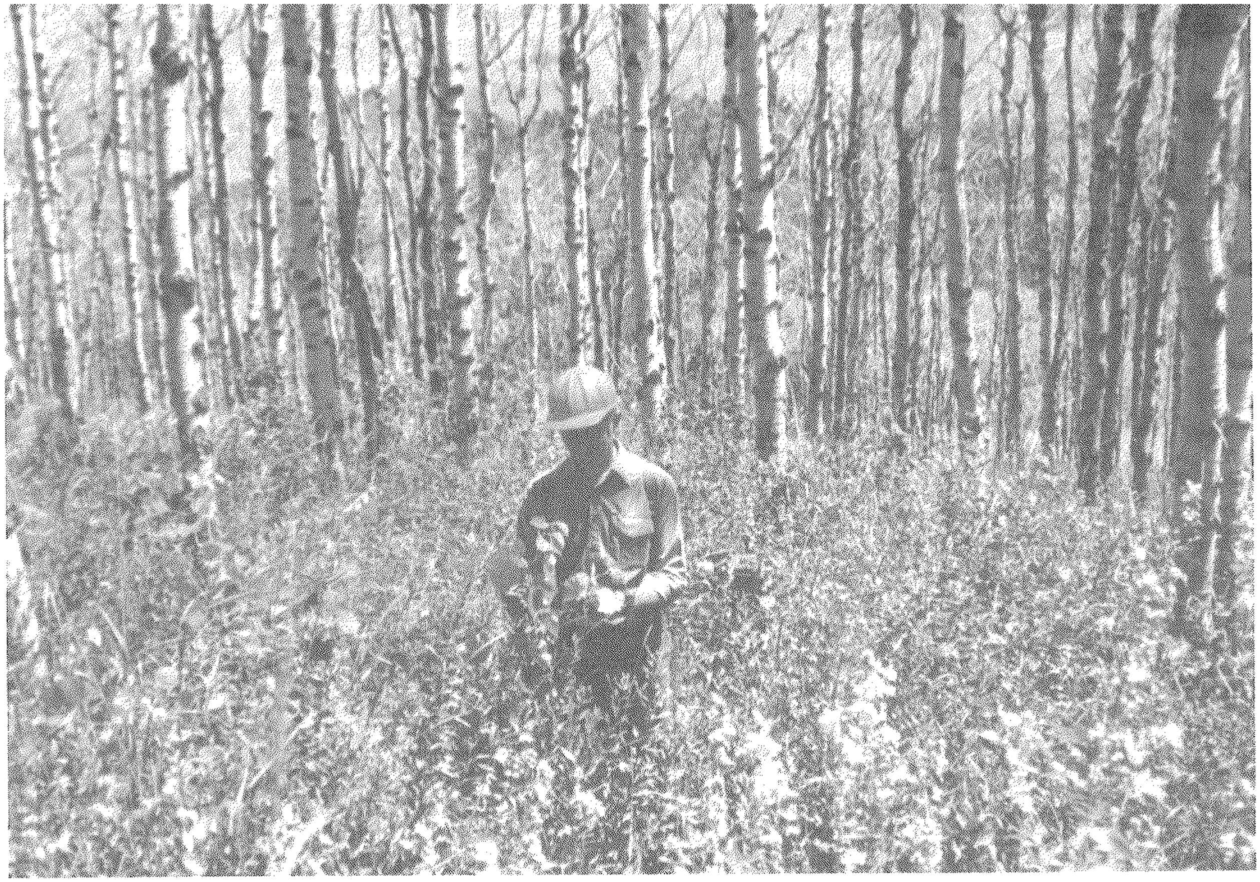

Figure 2—Three years after fire killed the aspen overstory, a dense stand of grasses, forbs, and aspen suckers occupies this Manning Basin site.

The understory in aspen usually is lush and contains many species palatable to both livestock and big game. Fire may increase at least the herbaceous component of this understory (Bartos and Mueggler 1981) (fig. 2). The attraction of burned areas to foraging ungulates, particularly big game, has led to frequent speculation that the forage on these burns is more nutritious than on adjacent unburned areas. This has been tested and found to be true for many vegetation types. The fiber content is often lower and the protein and phosphorus contents higher in the regrowth during the first couple years following fire (Blank 1984). However, no test of this hypothesis for the western aspen-shrub community could be found in the literature. Therefore, we conducted an experiment with the following objectives:

1. To determine nitrogen, calcium, and phosphorus concentrations in aspen sprouts and selected species of grasses, forbs, and shrubs common to both burned and unburned aspen communities.
2. To compare in vitro digestibilities for elk and for domestic sheep of these plant species from both treatments.

MATERIALS AND METHODS

We selected three sites in the Caribou National Forest about 20 miles (30 km) west of Afton, WY. All three had been prescribed burned in the autumn of 1981. Burn severity ranged from high (Manning Basin site) to moderately low (Snowdrift I and II sites). These sites were in the *Populus tremuloides/Amelanchier alnifolia—Symphoricarpos oreophilus* plant community. These characteristic tall shrubs grow within an herbaceous understory dominated by *Calamagrostis, Elymus, Lupinus*, or *Geranium* (Mueggler and Campbell 1982).

Plant samples were collected during the summers of 1982 and 1983 from the burned and adjacent unburned areas on each site. For the most part, we gathered only those species that made up the majority of forage and were common to both the burned and unburned areas. Each sample of a species consisted of material from 25 to 30 randomly selected plants. Woody plants were sampled by stripping the leaves and terminal segments of the current year's twigs. The entire aboveground portion of grasses and forbs was collected. Samples were immediately weighed to determine moisture content. They were put on ice in the field and frozen later that day. Prior to analyses, they were ovendried at 50 °C, weighed again, and ground to pass through a 1-mm screen.

The Tilley and Terry (1963) technique as modified by Moore (1970) was used to determine in vitro dry matter digestibility (IVDMD). Rumen fluids from elk and domestic sheep, both maintained on alfalfa hay and pellets, were used for the IVDMD analysis.

The concentrations of nitrogen, calcium, phosphorus, dry matter, and ash were determined for each sample. The macro-Kjeldahl technique (A.O.A.C. 1965) was used to determine nitrogen. Plant samples for determination of calcium and phosphorus were ashed at 500 °C, put into solution in an acid medium, and filtered. Phosphorus was determined with a spectrophotometer using the ammonium molybdate-ANSA method (Harris 1970), and calcium was determined using the EDTA titration technique (Allen and others 1974).

We subjected these data to an analysis of variance. There were three replications (sites), two treatments (burned and unburned), nine plant species, and several collection dates.

The major comparison for the first postburn year (1982) consisted of one date and five species; the major comparison for the second postburn year (1983) consisted of three dates and nine species. The five species analyzed from August 22, 1982, were: aspen, serviceberry (*Amelanchier alnifolia*), snowbrush (*Ceanothus velutinus*), chokecherry (*Prunus virginiana*), and pinegrass (*Calamagrostis rubescens*). Another test for the first field season used two dates (August 2 and 22) but only two species, aspen and pinegrass.

In 1983, the three dates were July 15, August 15, and September 15. The nine species included the same five species as in 1982 plus blue wildrye (*Elymus glaucus*), sticky geranium (*Geranium viscossissimum*), blue lupine (*Lupinus argenteus*), and heart-leaf arnica (*Arnica cordifolia*).

For a year-to-year comparison, the five species from August 22, 1982, were matched with the same species from August 15, 1983. We also made a comparison using only aspen and pinegrass for both August 2 and 22, 1982; and July 15 and August 15, 1983.

Additional analyses using the least squares estimator, or in case of no overall statistical significance, the Sheffe LSD test, were used to test for differences between species means (Neter and Wasserman 1974).

All differences discussed in this paper are significant at least at the 0.05 percent probability level.

RESULTS AND DISCUSSION

Plant phenological stages were observed to be similar on both burned and unburned areas. Forbs bloomed throughout the season. Thus, several phenological stages of forbs overlapped within and between the burned and unburned areas. Pinegrass produced many culms and flowers in the burned areas but only a few in the unburned areas. Shrubs on the burned areas neither flowered nor set seed during either summer. So, dates instead of phenological stages are used for comparisons.

Irrespective of burning, changes in forage quality occurred as the season progressed. In the second year, for example, the earliest sampling yielded the highest quality (table 1). Also, over the entire season, there were marked differences among species (table 2). Forbs had higher digestibilities than shrubs or grasses.

Fire improved forage quality during the first postburn growing season (1982). Aspen on the burned areas on August 2, 1982, had a better calcium/phosphorus ratio, higher elk digestibility, higher crude protein and phosphorus levels, and a lower calcium content than on the unburned sites. However, 3 weeks later only phosphorus and crude protein levels were greater on burned sites (table 3). At that time, all shrubs on the burned areas had higher crude protein levels. Two (serviceberry and chokecherry) had lower phosphorus levels, and chokecherry had a lower calcium level (table 4). In the second growing season (1983), there were no improvements in quality of either shrubs or forbs that could be attributed to burning.

Some of the changes in quality of shrubs could be due to changes in growth form on the burns. In early August of the first year, most shrubs on the burned areas were less than 1 ft (30 cm) tall and had fewer stems and larger leaves than on unburned areas. By late August, secondary branching had appeared and the plants were up to 2 ft (60 cm) tall. In the second summer, these shrubs were 3 to 5 ft (100 to 150 cm) tall, with more branches and smaller leaves. Thus, shrubs in early August of the first postburn year had lower stem-to-leaf ratios than they did later in that summer or in the second year.

Higher levels of phosphorus in plants from burned areas were found only in aspen and only on August 2 of the first year. All of the other samples from the burns had either lower levels of phosphorus or did not differ from the unburned sites (tables 3, 4, and 5). Our findings are similar to those of others (Halls and others 1952; Meenely and Schemnitz 1981; Swank 1958).

Table 1—IVDMD and nutrient concentrations of all forage species combined on three dates in 1983

Date	IVDMD		Protein	Calcium	Phosphorus
	Sheep	Elk			
	Percent				
July 15	[1]65.9	60.2	[1]16.3	[1]1.28	[1]0.33
August 15	58.6	61.6	12.5	1.57	.27
September 15	57.5	60.1	10.9	1.70	.29

[1]Significantly (p=0.001) different from values on other two dates.

Table 2—Average digestibility and nutrient concentration of each species in the second postburn summer; treatments, dates, and sites are pooled

Species	IVDMD Sheep	IVDMD Elk	Protein	Calcium	Phosphorus
Shrubs			*Percent*		
Populus tremuloides	[1]53.8a	55.5ab	15.4cd	1.45	0.26abc
Ceanothus velutinus	57.0b	57.8b	14.2bc	1.28	.21a
Amelanchier alnifolia	56.7ab	59.0b	14.6c	1.58	.43d
Prunus virginiana	55.2ab	58.7b	15.0cd	1.92	.36cd
Grasses					
Calamagrostis rubescens	55.6ab	52.5a	10.5a	0.81	.21a
Elymus glaucus	56.6ab	55.5ab	13.1b	1.11	.22a
Forbs					
Geranium viscossissimum	70.4cd	69.0c	13.1b	1.98	.39d
Lupinus argenteus	68.9c	67.7c	16.0d	1.55	.24ab
Arnica cordifolia	72.0d	69.9c	9.7a	1.99	.35bcd

[1]Within each column, the means not followed by a common letter are statistically different (p=0.05).

Table 3—Sheep and elk IVDMD, and concentrations of crude protein, phosphorus, and calcium of aspen and pinegrass that were collected on two dates (August 2 and 22, 1982)

Species	Date	Treatment	IVDMD Sheep	IVDMD Elk	Protein	Phosphorus	Calcium
					Percent		
Populus tremuloides	August 2	Burned	[1]43.5a	61.8d	21.7d	0.39d	1.47b
		Unburned	50.3a	51.8abc	15.8c	.24ab	1.78c
	August 22	Burned	57.9a	48.7ab	19.2d	.32cd	1.88c
		Unburned	53.5a	48.3a	14.2bc	.27b	1.86c
Calamagrostis rubescens	August 2	Burned	53.7a	54.7abc	13.5abc	.23ab	.54a
		Unburned	52.7a	48.9ab	10.3a	.23ab	.79a
	August 22	Burned	54.6a	57.1cd	11.5ab	.19a	.54a
		Unburned	56.8a	55.9bcd	10.5a	.20ab	.74a

[1]Means in columns not followed by a common letter are statistically different (p=0.05).

Table 4—Sheep and elk IVDMD, and concentrations of crude protein, phosphorus, and calcium of five forages collected on August 22, 1982

Species	Treatment	IVDMD Sheep	IVDMD Elk	Protein	Phosphorus	Calcium
		Percent				
Populus tremuloides	Burned	[1]54.7ab	47.8ab	19.1e	0.32cd	1.66c
	Unburned	49.4ab	47.5ab	14.1bc	.28bc	1.87cd
Ceanothus velutinus	Burned	49.1ab	47.4ab	18.2e	.23abc	.93ab
	Unburned	48.7ab	47.5ab	14.4c	.14a	1.20b
Amelanchier alnifolia	Burned	50.6ab	50.4ab	18.1e	.39d	1.75cd
	Unburned	48.2ab	44.2a	15.0cd	.57e	2.07de
Prunus virginiana	Burned	45.9ab	47.0ab	17.7e	.29bcd	1.64c
	Unburned	44.2a	45.2a	14.9cd	.60e	2.37e
Calamagrostis rubescens	Burned	51.6ab	52.9ab	11.4ab	.19ab	.55a
	Unburned	56.5b	57.6b	10.8a	.20ab	.73a

[1]Values within columns not followed by a common letter are statistically different (p=0.05).

Table 5—IVDMD and nutrient concentrations in five forage species collected on August 22, 1982, and August 15, 1983; sites and treatments are pooled

Species	Treatment	IVDMD Sheep First summer	IVDMD Sheep Second summer	IVDMD Elk First summer	IVDMD Elk Second summer	Crude protein First summer	Crude protein Second summer	Phosphorus First summer	Phosphorus Second summer	Calcium First summer	Calcium Second summer
		Percent									
Populus tremuloides	Burned	[1]54.7de	52.1cde	47.8abc	56.9ef	19.1h	14.1cdef	0.32bcde	0.17a	1.66	1.18
	Unburned	49.4bcd	49.3bcd	47.5abc	55.2de	14.1def	14.1def	.28abcd	.25abcd	1.87	1.67
Ceanothus velutinus	Burned	49.1bcd	54.1de	47.4abc	61.9f	18.2gh	14.5def	.23abc	.20ab	.93	1.34
	Unburned	48.7abc	53.0cde	47.5abc	60.9f	14.4def	15.0ef	.14a	.21ab	1.20	1.72
Amelanchier alnifolia	Burned	50.6cd	52.9cde	50.4bcd	57.0ef	18.1gh	15.6efg	.39de	.39de	1.75	1.36
	Unburned	48.2abc	52.2cde	44.2a	56.6ef	15.0ef	13.8cde	.57fg	.45fe	2.07	1.42
Prunus virginiana	Burned	45.9ab	55.1ef	47.0abc	59.6f	17.7gh	14.6def	.29bcd	.21a	1.64	1.56
	Unburned	44.2a	54.5de	45.2ab	58.7d	14.9ef	15.6efg	.60g	.37cde	2.37	1.90
Calamagrostis rubescens	Burned	51.6cd	49.6bcd	52.9de	46.7ab	11.4bc	6.8a	.19ab	.20ab	.55	.89
	Unburned	56.5ef	59.1f	57.6ef	56.2ef	10.4b	12.2bcd	.20a	.21ab	.73	1.27

[1]For each pair of columns (first and second summers), the means not followed by a common letter are statistically different (p=0.05).

Figure 3—One year after a severe stand-killing fire in the aspen there is almost a complete coverage of globemallow and pinegrass on this Manning Basin site.

The calcium concentration of plants was generally lower on burned areas than it was on nonburned areas. Lay (1957) reported similar findings. Lower calcium contents produce lower calcium/phosphorus ratios on these burned areas. The possibility of interference with phosphorus metabolism in the animal is reduced with low calcium/phosphorus ratios. Burning, at least in the first postburn year, improved calcium/phosphorus ratios by lowering them. Even then, with the exception of grass, all of our plant samples had much higher ratios than optimal for ruminants. Ratios of 1:2 to 2:1 are excellent, 2:1 to 3:1 are good, 3:1 to 5:1 are fair, and those larger than 5:1 are poor (Urness 1973). However, plants poor in phosphorus may be good sources of protein, energy, or other nutrients.

Pinegrass in the first postburn year was similar on both burned and unburned areas (tables 3 and 4). (Different August 22 values in tables 3 and 4 are due to different subsamples and runs on aspen and pinegrass; the data are correct.) By the next year, pinegrass on burned areas was significantly lower in digestibility and crude protein than on unburned areas (table 5).

Vegetative reproduction of perennial species usually occurs rapidly and vigorously after burning (Hadley 1970; Old 1969; Vogl 1965; Wright 1969). Shoots of herbaceous species produced after fire often are stiffer and more erect than on unburned sites (O'Connor and Powell 1963). Increased numbers of grass and forb flowers are stimulated by burning (Curtis and Partch 1950; Ehrenreich and Ackman 1963; Lemon 1949, 1968; Lloyd 1972), including pinegrass (Crane and others 1983; Weaver 1974). On our sites, pinegrass on the severely burned areas not only produced more biomass, but uniformly flowered and produced a seed crop as well (fig. 3).This flowering and seed production of pinegrass likely caused the decrease in its quality on the burned areas (Chapin and Van Cleve 1978; Van Soest 1982).

Flowering in forbs increased, too; but it is not usually associated with large changes in nutritive value, despite leaf loss through senescence (Van Soest 1982). Thus, the forbs had higher forage quality at the end of the season than did the grasses, even though their phenology was similar.

Our study showed that burning causes changes in the digestibility and nutrient content of selected species growing in common on burned and unburned sites. However, relatively much larger changes in forage species composition and structure occurred on these sites after fire (figs. 2 and 3). These, no doubt, were more important to ruminants than our documented changes in nutrient contents or digestibility (Canon and others 1987).

Fire, followed by an excellent growing season, stimulated a large increase in herbaceous biomass production. On inventoried plots in Manning Basin, the forbs, from a preburn base of 85 lb/acre (95 kg/ha), increased almost eightfold in the first postburn growing season and, in the second, about fifteenfold, to 1,254 lb/acre (1,405 kg/ha). Grass production increased from 280 lb/acre (315 kg/ha) to 646 lb/acre (724 kg/ha) in the first year and to 516 lb/acre (578 kg/ha) in the second. The shrub component was reduced as dramatically as the forb component increased. (Brown and DeByle, in preparation, and unpublished data on file at the Intermountain Fire Sciences Laboratory, Forest Service, Missoula, MT.)

The forb species that dominated the postburn vegetation were not those sampled extensively in this study. A globemallow (*Iliamna rivularis*) that was not found prior to burning was the most abundant forb on these sites afterwards. Fireweed (*Epilobium angustifolium*) was also common on the burned areas but was nonexistent on the control areas. Both of these forbs were sampled in the second year. They had digestibilities over 80 percent throughout the second summer. Crude protein levels were also high, averaging 20 percent for fireweed and 18 percent for mallow. Wherever cattle and sheep grazed on the burned sites, these two forbs were highly preferred, often grazed to ground level. This was especially true in the first postburn year when these plants were quite succulent. Thus, burning introduced highly preferred and nutritious forages that otherwise would not have occurred on these sites. Free-ranging tame elk preferred the burned sites in the second and third summers after treatment. The composition and quality of their chosen diets are reported by Canon and others (1987).

CONCLUSIONS

The benefits of these prescribed fires to ruminants, both wild and domestic, are substantial during the summer and autumn of the first several postburn years. Our burns provided a more nutritious forage resource than before, when shrubs dominated these sites. Forage also became more accessible because dense shrub motts were reduced. The height of forage, after burning, was totally within the grazing zone, in contrast to unburned sites dominated by shrubs, where much of the biomass often is above the reach of grazing ungulates. Thus, on these burned areas, animals could obtain a high-quality diet with relative ease (Canon and others 1987).

Generally, with or without burning, the nutritive quality of aspen understory is high (Collins and Urness 1983, Canon and others 1987). The quality of our selected species improved only in the first postburn year. Wood (1988) found similar transient improvement in pine understory in South Carolina. In our study, we found that few species dropped below 50 percent digestibility even in late September. The shrubs averaged about 14 percent crude protein for all dates. The grasses and some of the forbs decreased to about 7 percent crude protein in late September, but still within the maintenance requirements for at least adult mule deer (Dietz 1965). All of the plants were still green and growing in September.

Prescribed burning increased forage quality of species that were common to both burned and adjacent unburned sites, but only briefly. By the second postburn year, the quality of most forages did not differ significantly between treatments. Despite the inconsistent and transient improvement in quality of individual forage species, prescribed burning remains a useful tool to alter forage species composition and forage availability in the aspen-tall shrub community.

REFERENCES

Allen, S. E.; Grimshaw, H. M; Parkinson, J. A.; Quarby, C. 1974. Chemical analysis of ecological materials. New York: John Wiley Sons; Halsted Press. 565 p.

Association of Official Agricultural Chemists. 1965. Official methods of analysis. 10th ed. Washington, DC.

Bartos, D. L.; Mueggler, W. F. 1981. Early succession in aspen communities following fire in western Wyoming. Journal of Range Management. 34: 315-318.

Blank, D. L. 1984. Forage quality comparison of burned and nonburned aspen communities. Logan, UT: Utah State University. 74 p. M.S. thesis.

Brown, J. K.; DeByle, N. V. [In preparation]. Effects of prescribed fire on biomass and plant succession in western aspen. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Missoula, MT.

Canon, S. K.; Urness, P. J.; DeByle, N. V. 1987. Habitat selection, foraging behavior, and dietary nutrition of elk in burned aspen forest. Journal of Range Management. 40: 433-438.

Chapin, F. S., III; Van Cleve, K. 1978. Plant nutrient absorption and retention under differing fire regimes. In: Fire regimes and ecosystem properties. Gen. Tech. Rep. WO-26. Washington, DC: U.S. Department of Agriculture, Forest Service. 301-321.

Collins, W. B.; Urness, P. J. 1983. Feeding behavior and habitat selection of mule deer and elk on northern Utah summer range. Journal of Wildlife Management. 47: 646-663.

Crane, M. F.; Habeck, J. R.; Fischer, W. C. 1983. Early postfire revegetation in a western Montana Douglas-fir forest. Res. Pap. INT-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32 p.

Curtis, J. D.; Partch, M. L. 1950. Some factors affecting flower production on *Andropogon gerardi*. Ecology. 31: 577-578.

DeByle, N. V.; Bevins, C. D.; Fischer, W. C. 1987. Wildfire occurrence in aspen in the interior western United States. Western Journal of Applied Forestry. 2: 73-76.

Dietz, D. R. 1965. Deer nutrition research in range management. Transactions of the North American Wildlife and Natural Resources Conference. 30: 274-285.

Ehrenreich, J. H.; Ackman, J. M. 1963. Effect of burning on seedstalk production of native prairie grasses. Proceedings, Iowa Academy of Sciences. 64: 205-212.

Hadley, E. B. 1970. Net productivity and burning responses of native eastern North Dakota prairie communities. American Midland Naturalist. 84: 121-135.

Halls, L. K.; Southwell, B. L.; Knox, F. E. 1952. Burning and grazing in Coastal Plain forests. Coll. Agric. Bull. 51. Athens, GA: University of Georgia. 33 p.

Harris, L. E. 1970. Nutrition research techniques for domestic and wild animals. Vol. I. Logan, UT: Utah State University, Department of Animal Science.

Jones, J. R.; DeByle, N. V. 1985. Fire. In: DeByle, N. V.; Winokur, R. P., eds. Aspen: ecology and management in the Western United States. Gen. Tech. Rep. RM-119. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 77-81.

Lay, D. W. 1957. Browse quality and the effects of prescribed burning in southern pine forests. Journal of Forestry. 65: 826-828.

Lemon, P. C. 1949. Successional responses of herbs in the longleaf-slash pine forest after fire. Ecology. 30: 135-145.

Lemon, P. C. 1968. Effects of fire on an African plateau grassland. Ecology. 49: 316-322.

Lloyd, P. S. 1972. Effects of fire on a Derbyshire grassland community. Ecology. 53: 915-920.

Meenely, S. C.; Schemnitz, S. C. 1981. Chemical composition and in vitro digestibility of deer browse three years after a wildfire. Southwestern Naturalist. 26: 365-374.

Moore, J. E. 1970. In vitro dry matter and organic matter digestion. In: Harris, L. E., ed. Nutrition research techniques for domestic and wild animals. Vol I. Logan, UT: Utah State University, Department of Animal Science: p. 5001(1-6).

Mueggler, W. F.; Campbell, R. B. 1982. Aspen community types on the Caribou and Targhee National Forests in southeastern Idaho. Gen. Tech. Rep. INT-294. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 32 p.

Neter, J.; Wasserman, W. 1974. Applied linear statistical models. Homewood, IL: R. D. Irwin. 474 p.

O'Connor, K. F.; Powell, A. J. 1963. Studies in the management of snow-tussock grassland. I. The effects of burning, cutting, and fertilizer on narrow-leaved snow-tussock at a mid-altitude site in Canterbury, New Zealand. New Zealand Journal of Agriculture Research. 6: 354-367.

Old, S. M. 1969. Microclimates, fire and plant production in an Illinois prairie. Ecological Monographs. 39: 355-384.

Shepperd, W. D. 1981. Stand characteristics of Rocky Mountain aspen. In: DeByle, N. V., ed. Situation management of two Intermountain species: aspen and coyotes: symposium proceedings. Vol. I, Aspen. Logan, UT: Utah State University: 22-30.

Swank, W. G. 1958. The mule deer in Arizona chaparral. Wildlife Bull. 3. Phoenix, AZ: Arizona Game and Fish Dept. 109 p.

Tilley, J. M. A.; Terry, R. A. 1963. A two-stage technique for the in vitro digestion of forage crops. Journal of British Grassland Society. 18: 104-111.

Urness, P. J. 1973. Chemical analyses and in vitro digestibility of seasonal deer forages. Part II. In: Deer nutrition in Arizona chaparral and desert habitats. Spec. Rep. 3. Phoenix, AZ: Arizona Game and Fish Department: 39-52.

Van Soest, P. J. 1982. Nutritional ecology of the ruminant. Corvallis, OR: O & B Books. 373 p.

Vogl, R. J. 1965. Effects of spring burning on yields of brush prairie savanna. Journal of Range Management. 18: 202-205.

Weaver, H. 1974. Effects of fire on temperate forests: western United States. In: Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press: 279-320.

Wood, G. W. 1988. Effects of prescribed fire on deer forage and nutrients. Wildlife Society Bulletin. 16: 180-186.

Wright, H. A. 1969. Effect of spring burning on tobosa grass. Journal of Range Management. 22: 483-533.