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Forage Quality Comparison of Burned and Nonburned Aspen Communities

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FORAGE QUALITY COMPARISON OF BURNED AND NONBURNED ASPEN COMMUNITIES

by

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of the requirements for the degree
of
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To Mom and Dad,

with all my love

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ABSTRACT

Forage Quality Comparison Between Burned and Nonburned Aspen Communities

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The objectives of this study were to assess the effects of prescribed burning on herbaceous and browse forage quality in the aspen forest type for elk and domestic sheep.

Plant samples of selected forage species were taken from burned and nonburned plots within three different prescribed burns in southeastern Idaho. These samples were analyzed for in vitro dry matter digestibility, crude protein, calcium and phosphorus. Data were analyzed using the analysis of variance.

There was little improvement in forage quality as a result of prescribed burning, with some reduction in quality in 1983 exhibited by pinegrass (Calamagrostis rubescens). Aspen on August 2, 1982 had improved elk IVDMD and Ca/P ratios, crude protein and phosphorus levels and decreased calcium content on the burned versus the nonburned areas. By August 22, 1982, only crude protein levels were improved. All of the shrubs analyzed for that date had improved crude protein levels on the burned versus the nonburned areas, but only serviceberry had higher phosphorus levels.

In 1983, none of the shrubs or forbs had improved forage quality.

Pinegrass decreased in IVDMD and crude protein on the burned areas, possibly due to a more rapid maturation and increased seed production.

Other benefits from prescribed burning included a changing species composition from dense shrub motts to more palatable and nutritious forbs that are not found on unburned areas. This reduction in shrubs also led to greater access of animals to available forage.

The aspen type was shown to have a nutritious and valuable understory, irrespective of prescribed burning.

(74 pages)

INTRODUCTION

Quaking aspen (Populus tremuloides) is the most widely distributed deciduous tree in North America, occupying approximately 3 million hectares in the western United States (Green and Van Hooser 1983). This type is usually a conspicuous element at lower and middle elevations, where it often forms a transition zone between shrub rangelands and conifer forests. Aspen-dominated sites are generally regarded as prime multiple resource areas. As an important wildlife habitat, aspen provides palatable and nutritious browse, and the herbaceous understory is more productive and diverse than in coniferous stands (Reynolds 1969, Kranz and Linder 1973). This understory is also favored by livestock (Cook and Harris 1968). Other multiple resource values include excellent watershed protection (Betters 1976, Hronek 1976), aesthetics and recreation. This western montane type has had little commercial value and thus has not been intensively managed, unlike the widespread eastern type which has been heavily utilized, primarily for pulpwood and chipboard.

Currently, however, the Intermountain Forest and Range Experiment Station and Region 4 of the Forest Service are conducting research on aspen regeneration because many aspen stands, especially on big game winter ranges in the Intermountain Region, are either mature or deteriorating (Krebill 1972). Traditionally, this general decline of aspen communities was attributed to excessive utilization of aspen by populations of elk (Cervus elaphus) and mule deer (Odocoileus hemionus), that congregate on these areas in winter, especially in western National Parks (Grimm 1939, Ratcliff 1941, Packard 1942, Gysel 1960). Not only do wild ungulates consume sprouts that might otherwise replace dying overstory, they also cause injuries that presumably induce susceptibility of aspen to disease (Krebill 1972). Studies of aspen production, using game exclosures, did show an increase in aspen, but regeneration was not sufficient to restore stands to former levels (Gruell and Loope 1974). After animals are allowed to graze the area again, this amount of reproduction becomes insignificant. Thus, it has become obvious that other abiotic and biotic factors are involved.

Aspen is seral on most sites, and without catastrophic events such as cutting, burning, or severe outbreaks of disease or insects, many aspen communities have shifted successionally toward conifers (Mueggler 1976) or brush domination on drier sites. These stands provide substantially less forage (Kranz and Linder 1973) and water yields (Jaynes 1978) than younger, healthier stands. Many biologists believe that fire suppression in the last hundred years has had a negative impact on aspen establishment and regeneration (Hoff 1957; Morgan 1969; Patton and Avant 1970; Houston, 1973, 1983; Gruell and Loope 1974) causing the total area of aspen to decline. The reintroduction of fire by way of prescribed burning is one way of stopping this succession and allowing aspen to regenerate from root suckers (up to 125,000 per ha, depending on the site, (Jones 1974), more rapidly than conifers can invade by seed. Intermittent fires are necessary for the development of large expanses of seral aspen vegetation, since sucker numbers would decline over time by natural thinning and conifers would again dominate such sites in 80-400 years without this disturbance (Bartos

1978). Properly implemented, prescribed burning in the aspen ecosystem would result in a mosaic effect, contributing to the enhancement of diversity and creation of additional edge. This fire regime would provide ungulates abundant browse and a greater total forage resource. Other potential benefits of prescribed burning might include the reduction of dense, rank and/or overmature growth, stimulation of crown or root sprouting, and increase in the nutritional value of the forage.

The purpose of this study was to contribute to the overall information obtained in the parent study (Brown and DeByle 1981) of burning in the aspen ecosystem. The specific objective of this study was to assess the effects of prescribed burning on herbaceous and browse forage quality in the aspen forest type for elk and domestic sheep. Samples from selected forage species on burned sites were compared to samples of the same species on adjacent unburned sites.

Objectives and Hypotheses

Objective 1: To determine the nitrogen, calcium and phosphorus contents of selected species of grasses, forbs, aspen sprouts and shrubs from burned and associated unburned macroplots.

Hypothesis 1: Nutrient levels do not differ significantly in the same forages on burned and adjacent unburned aspen sites.

Objective 2: To compare forage digestibilities (in vitro) of the burned sites with those of the unburned sites for two animal species (elk and domestic sheep).

Hypothesis 2: There are no statistically significant differences in herbaceous forage or browse digestibility between burned and unburned aspen communities.

LITERATURE REVIEW

Nutrient Cycling

The recycling of nutrients by fire has some direct effects on a site that may cause many indirect short- and long-term effects. Fire converts biomass into gases while releasing tremendous amounts of energy and leaving ash with highly concentrated nutrients on the soil. In this way, the soil is exposed, heated and enriched. Indirectly, through this heat, nutrient release, and fuel consumption, fire will affect the on-site flora and fauna as well as the soil. Martin (1981) stated that the fate of nutrients depended on the nature of the particular nutrients. Most cations stay on the site after a fire, while 60-80% of the nitrogen consumed in fuel is lost from the site in smoke. Usually, however, more nitrogen is made available on the site and may be replaced by increased nitrogen fixation by soil microorganisms on the site (Ahlgren and Ahlgren 1965; Lewis 1964; Jorgensen and Wells 1971). Conversely, Vlamis and Cowan (1961) stated that the reason nitrogen concentrations increased on a site after a fire was due to the nitrogen that was released from vegetation and organic matter and returned to the soil in the ash. Stark (1973), in a Jeffrey pine (Pinus jeffreyi) forest in California and Sharrow and Wright (1977) in a tobosa grassland in Texas, suggested that fire accelerated organic matter decomposition. Christensen (1977) showed that burning increased the rate of ammonification and/or nitrification. Frequently after a fire, the herbaceous vegetation contains a large portion of native leguminous plants which increase soil nitrogen fixation (Lewis and Harshbarger 1976). Fire was also shown to alter the soil pH which could either increase or decrease availability of phosphorus, nitrogen and various cations depending on initial conditions and the nature of the fire-induced pH change (Daubenmire 1968, Viro 1974, Martin 1981). McKee (1982) showed that prescribed burning consistently increased the amount of available phosphorus. Another important indirect effect of fire is enhanced nutrient availability. By eliminating plants, competition for nutrients and water among remaining individuals is reduced (Chapin and Van Cleve 1978). These indirect effects may last for several years and over time may be more important in explaining improved plant growth after a fire than the direct release of nutrients to soil in ash (Woodmansee and Wallach 1978).

Forage Quality

At high available nutrient concentrations, plants exhibit "luxury consumption" (Epstein 1972) absorbing nutrients in excess of quantities immediately used in growth. The resulting high nutrient status allows plants to produce leaves with high photosynthetic rates but which require a large nutrient investment per gram of leaf. Production is rapid and a high relative growth rate is achieved because of the rapid gain of both carbon, from the increased rate of photosynthesis, and increased nutrient uptake (Chapin and Van Cleve 1978). This, along with the high root-to-leaf ratio, and the increased nutrient absorption per unit root (Loneragan and Asher 1967, White 1973) of resprouting species are generally responsible for high tissue nutrient concentrations.

As succession progresses, light and nutrients become limiting to growth, and plants must survive the stresses of increased competition. It becomes advantageous for the plant to produce leaves with a lower nutrient investment per gram of leaf and thus a lower growth rate (Mooney 1972, Orians and Solbrig 1977). This results in lowered photosythetic rates and lower tissue nutrient content (Chapman and Pratt 1961, Odum 1969, Vtousek and Reiners 1975).

Rundel and Parsons (1980) concluded that stands at 16 years of age represent the peak of productivity in the California chaparral. Their rational was based on allocation of nitrogen and phosphorus to photosynthetic tissue, which declined sharply in stands after 16 years. They suggested that the limited amounts of available nutrients become tied up in plant biomass and that fire provides a natural means of recycling nutrients. Zinke (1977) concluded that mineral cycling in fire-type ecosystems is apparently dominated by periodic ashing of the vegetation and organic material on the soil surface. Rundel and Parsons (1980) further noted that fires in this vegetation type occurred at 15-20 year intervals, which is reasonably consistant with their data on temporal nutrient distributions.

In contrast, Christensen (1977) hypothesized that the increased nutrient concentrations of post-fire sprouts in the California chaparral were merely an artifact of a change in the age of the tissue sampled. For example, on cut-over, long-leaf pine (Pinus palustris) sites in Louisiana, mowing and raking away biomass was compared with burning (Grelen and Epps 1967). Yields and nutrient contents of forages on the two treatments were almost identical. On another longleaf pine plantation, the increase in nutrient concentration of sawgrass (Cladium jamaicense) leaves following burning was comparable to that of plants that were simply clipped. The young leaves and stems had relatively small amounts of structural tissue and on a dry-weight basis had high concentrations of nutrients associated with metabolism (nitrogen, phosphorus and potassium) and low concentrations of stucturally bound elements such as calcium (Milthorpe and Moorby 1974, Chapin et al. 1975). Reynolds and Sampson (1943) showed that chaparral sprouts in California contained more water, minerals and protein than older uncropped shrubs. New growth of forage plants, including woody browse plants, is generally less fibrous and more palatable than mature growth. This is especially true in post-burn vegetation where all vegetation is regrowth, which does not have to compete with existing mature vegetation. Whatever the case, these immediate but short-term increases are available to herbivores on a fairly consistent basis in types, such as ponderosa pine (Pinus ponderosa) that burn frequently. Even though the entire forest floor may not have burned, there are nutritious patches of forage scattered throughout (Severson and Medina 1983).

Almost all of the following studies comparing burned and unburned communities demonstrate this short-term increase of nutrients. Many of them reported increases in nutrient levels following the burn with a decline to preburn levels in one to three years, suggesting that these decreases in rates of nutrient uptake, tissue nutrient concentration and relative growth rates are fairly rapid as succession proceeds. Most of these studies reported changes in crude protein, phosphorus, and calcium levels, but few dealt with digestibility or fiber contents of forage. The reason for this is that crude protein and phosphorus are generally considered the most limiting nutrients for ungulates (Shepherd et al. 1953, Dietz et al. 1962, Dietz 1965, 1972; Wallmo et al. 1977). Yet the nutritive value of a forage is a function of its chemical content and its digestibility (Hale et al. 1962, Van Soest 1982). A forage could have adequate nutrient levels but be unavailable to the ruminant because of low digestibility. Thus to adequately analyze the effects of fire on forage quality, digestibility as well as nutrient content should be assessed.

A recent study by Kroneman (1982) found that the increased quality of post-burn browse regrowth in west Texas was short lived. Digestible organic matter, digestible energy, phosphorus, and crude protein showed sharp first-year increases in desert ceanothus (Ceanothus greggii), mountain mahogany (Cercocarpus montanus), and oak (Quercus sp.) following a burn, but were not evident at the beginning of the second growing season. Hilmon and Hughes (1965) also reported short-lived increases in the protein content of burned pineland threeawn (Aristida stricta) in southern Florida. After three months, there was no discernible difference.

Dewitt and Derby (1955) found higher protein contents in flowering dogwood (Cornus florida), round-leaf greenbriar (Smilax rotundifolia) and red maple (Acer rubrum) foliage the season following a low-intensity fire in an eastern Maryland forest. No effects were evident the second season. In a high-intensity fire, however, they found significant increases in nutrients in these species, as well as in oak

(Quercus alba) which lasted for at least two years. Another study (Stark 1980) reported that slash burning in a Douglas fir (Psuedotsuga menziesii) clearcut in Montana, under conditions producing very light to light burn intensities (<66°C), resulted in almost no enrichment of biologically essential nutrients in the foliage. Studies on the Lubrecht Experimental Forest in Montana also in the Douglas fir type (Stark and Steele 1977) showed that surface soil temperatures usually must reach 300°C for significant releases of nutrients that may show up in concentrations in the forage.

Significant differences in ash, calcium, ether extract, and acid detergent fiber contents of browse three years after a spring wildfire in mountain oak shrubs were shown by Meneely and Schemnitz (1981) in New Mexico. They found no significant differences, however, in crude protein, phosphorus or in vitro digestibility in forages on burned and unburned sites.

Lay (1957), in an east-Texas pine forest, concluded that burning at any season increased protein and phosphoric acid content of browse but most of the benefits disappear in a year or two. Leege (1969) found significantly higher crude protein levels for serviceberry (Amelanchier alnifolia) in Idaho on a spring than on a fall 1967 burn, when measured in February 1968. He found lower levels of crude fiber and nitrogen-free extract on both the spring and fall burns. The only species that showed higher phosphorus levels on the burn was ninebark (Physocarpus malvaceus). He concluded that nutrient changes brought about by spring burning would last for at least two winter-browsing seasons, whereas fall burning would only last for one.

Pearson et al. (1972) reported that crude protein, phosphorus and in vitro digestibilities were higher in forages from a burned area of ponderosa pine in Arizona the first growing season. Increases in digestibilities and phosphorus levels lasted through the second growing season, while increases in protein persisted only through the initial growing season. In decadent California chaparral, Hendricks (1977) found that after burning, brush fields produced 800 kg/ha of woody browse with a protein content of 6%, compared with 50 kg/ha with a 1% protein content before the fire. In pine forests of the Southeast, Stransky and Halls (1978) indicated similar improvement in nutrients following prescribed burning. Thackston et al. (1982) found that leaves of mountain-laurel kalmia (Kalmia latifolia) were higher in crude protein, moisture and phosphorus and lower in crude fat and crude fiber on burned sites than on unburned sites. They also found no apparent differences for nitrogen-free extract, ash and calcium. Greene (1935), however, showed that grasses from burned areas contained more calcium, protein and phosphorus. This lasted only a few months. Einarsen (1946) showed that browse plants in burned areas were higher in protein and enabled deer to survive better in winter months, and more importantly, to attain significantly greater body size, which is a reflection of improved nutritional status.

Not every study reported increases in forage quality. Hobbs and Spowart (1983) found that improvements in forage protein contents and digestibility resulting from burning winter range of mountain sheep (Ovis canadensis) averaged less than a few percentage points. They did find, though, that sheep diets were greatly improved by burning. This was achieved through changing patterns of diet selection. Much more green grass, which had a higher crude protein content than any other forage on the site, was chosen. The animals appeared to be able to find the grass much more readily on burned plots than on unburned, apparently because it was more available. Reduced "interference" from standing crop.

Swank (1958), in the Arizona chaparral, found increased protein contents from one but not from another, 9-month-old burn. He also indicated a higher average protein content in forage plants collected in a 5-year-old burn, but not in those from 3- or 8-year-old burns. Phosphorus was lower on all of the burns than on the unburned areas. These conflicting results reinforce what Bendell (1974) stated, that the relationships among burning, release of nutrients, and what may be taken up by plants, are very complex.

Ungulate Response

Other effects of prescribed burning have greater longevity. Fire has the ability to alter quantity and availability of preferred forages which are more productive and accessible after a burn (Ffolliott and Thill 1977, Lowe et al. 1978). Hilmon and Hughes (1965) indicated that removal of dense brush cover permitted growth of herbaceous vegetation, resulting in an increased and more diverse food supply. Species that are too tall for ungulates to reach before burning frequently resprout prolifically. The first year after burning shrubs in northern Idaho, all browse was below 2.1 m in height and even the second year 95% of the browse was still available to elk, whereas on the unburned plots only 28% was available (Leege 1969). Ceanothus seeds, which lie dormant in the litter for years, germinate rapidly following fire, and provide many new shoots (Curtis 1952, Quick 1959, Pearson et al. 1972). Young shoots are much less fibrous and more abundant than older shoots on burns and thus deer populations rise on these areas (Asherin 1973, Regelin and Wallmo 1978). This response often starts immediately after a fire when animals gather on the blackened surface. Komarek (1967) noted cases in Africa where native animals were found grazing on recently burned areas. Cattle are so attracted to burned areas that prescribed fire has been used to develop grazing systems based on rotation burning in the Southeast (Duvall and Whitaker 1964). Forage preferences of deer were shown by Hines (1973) to be closely linked to fiber and protein levels. Studies by Lowe et al. (1978) have shown that deer will increase 10-20 fold when forests are burned or logged. The areas remain good deer range for at least 20 years (Lyon and Stickney 1966).

Ovulation rates and weights of deer are also higher on burned areas (Biswell 1972). Taber and Dasmann (1958) found that burning in the California chaparral supplied a great deal of nutritious forage to deer whose populations responded with a rapid increase. Cattle spend more time grazing on burns and gain more weight than on unburned areas (Halls et al 1952, Shepherd et al. 1953, Hilmon and Hughes 1965, McGinty et al. 1983). Hines (1973) reported a significant decrease in deer weights in Oregon as the seral vegetation developed and deer populations increased to a maximum. Leege (1969) found that burned shrubs increased in palatability as evidenced by heavier use by elk on burned than unburned areas. The increase in palatability was also shown by the increase in size of twigs that the elk would browse. White-tailed deer (Odocoileus virginianus) use was higher on burned than unburned aspen areas in heavily wooded northern Wisconsin (Vogl 1969). Ffolliott and Thill (1977) noted that mule deer, cattle, and elk use was higher on clearcuts where slash had been piled and burned than in those in which the slash had been piled but not burned.

The response of ungulates to burned areas generally continues past the time that nutrient levels are highest. Kruse (1972) reported that elk and mule deer use of a ponderosa pine forest that had been burned increased significantly for two years. Elk use leveled off the third year, but mule deer use continued to increase. Roppe and Hein (1978) indicated that during winter mule deer and elk used a burned area more than an adjacent unburned lodgepole pine (Pinus contorta) stand in Colorado eight years after a wildfire. In Arizona, Lowe et al. (1978) found that use of ponderosa pine forests by mule deer declined during summer and fall the first year after a fire, then increased 2.5 times compared to the control for the rest of the 20-year evaluation period. Use by mule deer in the winter and spring also declined the first year, returned to control level for a few years, then increased 10 times that of the control. Use by elk in the summer and fall was similar, but winter-spring use was higher than the control throughout the 20-year period, with the highest postfire use at 7 years after burning. McCulloch (1968) noted higher mule deer use of burned areas in pinyon-juniper stands in northern Arizona. Ages of the burned areas ranged from 4-12 years on prescribed burns to 15 years on a wildfire burn. Blood (1966) noticed on aerial surveys in Manitoba during February that the greatest elk densities were on areas burned two years earlier. Martinka (1976) also found that elk wintering in Montana responded to fire by expanding population levels until they hit peak numbers within 25 years of a major fire.

So, even though the nutritional benefits of fire are short-lived, there are many other positive aspects of habitat change that make prescribed burning desirable. Burning would likely be most effective in relatively small patches at close spacing with some area treated every year or two. This would result in a mosaic of variable-aged plant communities that would have maximum edge and habitat diversity (Lowe et al. 1978), increased production of preferred forage (McCulloch 1969, Kruse 1972, Barsch 1977, Davis 1977, Lowe et al. 1978) and increased forage diversity (Davis 1977). All of these aspects are possible explanations for the long-term attractiveness of burned areas to ungulates.

STUDY SITES

Primary study sites were chosen in the Caribou National Forest in the Montpelier Ranger District, about 30 km west of Afton, Wyoming (Figure 1). The sites, ranging in elevation from 2100m to 2300m, are: Manning Basin and Snowdrift I and II, located on the Webster range. These are three of the study areas selected by the Forest Service and the Intermountain Forest and Range Experiment Station for the parent study on burning in the aspen ecosystem (Brown and DeByle 1981). In these areas, burning prescriptions were developed and tested in October 1981 for several difficult-to-burn aspen communities, and plant samples were collected during the summers of 1982 and 1983. The Manning Basin fire was a severe fire, burning to mineral soil on many hectares. The Snowdrift fires were spotty with patches of litter and organic matter remaining throughout.

Mean annual temperature, taken at Border, Wyoming, about 25 km east of Monpelier, Idaho, is approximately 3.0°C, and the annual precipitation averages 500mm with the highest precipitation occurring in winter and early summer (Steele et al. 1983).

Brown et al.(1983), classified these stands as POTR/AMAL-SYOR communities. This type is characterized by the presence of a tall shrub layer in which *Amalanchier alnifolia*, *Prunus virginiana* or *Symphoricarpos oreophilus* (or any combination) are prominant. The herbaceous component of the vegetation is usually dominated by one or more of the following species: *Calamagrostis rubescens*, *Elymus glaucus*, *Lupinus argenteus*, and *Geranium viscossissimum* (Mueggler and Campbell 1982).

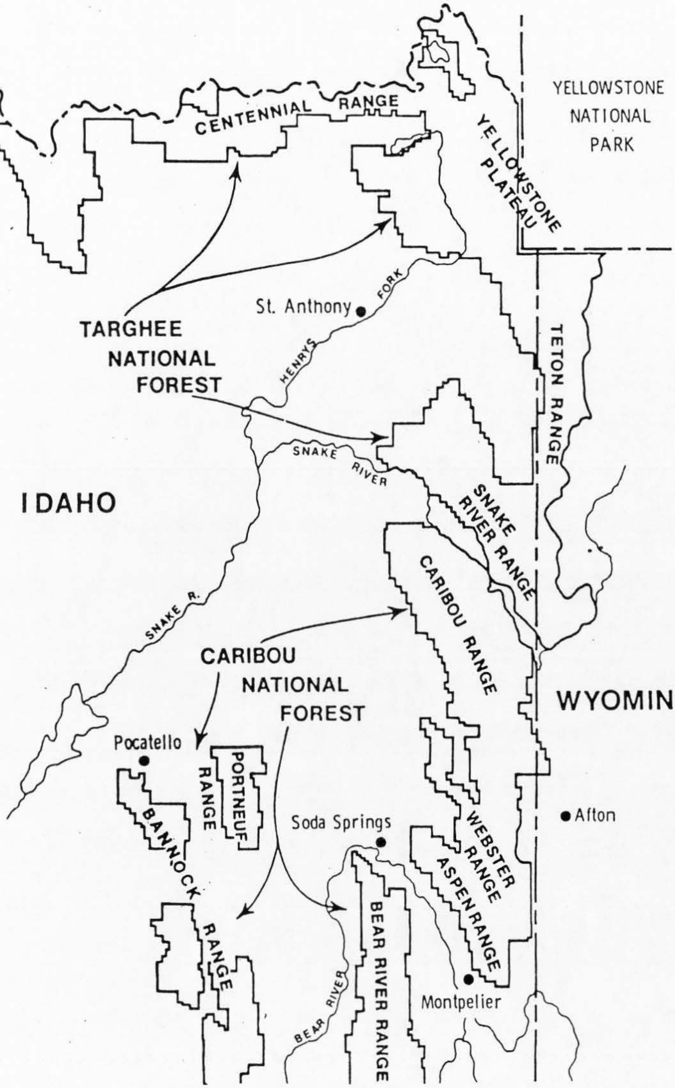


Figure 1. The Targhee and Caribou National forests in southeastern Idaho

METHODS

Plant Sampling

Composited samples of whole plants and plant parts were hand plucked from approximately 25-30 randomly selected plants that comprised a majority of the forage species shared in common on burned and unburned plots. Nine species in all were collected once a month from July through September which provided a seasonal comparison of quality in addition to the primary treatment comparison (ie., burned vs. nonburned). The shrubs were collected by stripping the leaves and terminal segments of current year's growth, while entire plants were collected for the grasses and forbs. The samples were weighed in the field for calculations of dry matter content and immediately put on ice to arrest their physiological processes. The samples were then taken to Logan where they were frozen until they could be oven-dried at 50^{o}C to a constant weight. After oven-drying, the samples were ground in a Wiley mill to pass through a 1 mm screen, and then stored in glass jars for later analysis.

In Vitro Dry Matter Digestibility

The Tilley and Terry (1963) technique of determining in vitro dry matter digestibility was used with modifications from Moore (1970). The procedure consisted of a 48-hour fermentation period in which rumen microorganisms from donor animals broke down structural carbohydrates into soluble components and a 46-hour stage of protein breakdown by incubation in hydrochloric acid-pepsin solution. Inocula of microorganisms from the rumens of elk and sheep (which were available on the Utah State University campus) were collected in the early morning following feeding during the animal's ruminating period. The elk were maintained on standard diets of alfalfa hay and balanced ration pellets, while the sheep were maintained on alfalfa hay which assured relative uniformity of microorganism populations. The first year, the rumen fluid was stomach-pumped from one elk. The second year, three elk were sacrificed and the entire contents of the rumen were taken to the laboratory. The same rumenally fistulated sheep was used both years. The fluid, no matter how it was collected, was rushed to the laboratory where it was strained through cheesecloth to remove solids (Pallesen 1979), and temporarily stored in a large bottle of artificial saliva through which carbon dioxide gas was bubbled continuously.

Following the acid/pepsin stage, the contents of each centrifuge tube were transferred to previously tared Gooch crucibles, filtered, and oven-dried at 105°C. Contents of the crucibles were dried to a constant weight and cooled in a desiccator. The apparent digestibilities of the individual forage species were calculated by the following formula:

$$\frac{\text{Initial dry matter} - (\text{Residual dry matter} - \text{Dry matter in blank})}{\text{Initial dry matter}}$$

These digestion coefficients were based on average values of replicated tubes (3 per sample) corrected for dry matter in the inocula by blank tubes. Outlier values were rejected if one of the three tubes had a value that departed more than 5 percentage points from the average of the other two tubes.

Chemical Analysis

Three chemicals, nitrogen, calcium and phosphorus, were monitered along with the routine dry matter and ash determinations that were necessary for assessment of the in vitro digestibilities. The macro-Kjeldahl technique (A.O.A.C. 1965) was used to determine nitrogen. For the determination of calcium and phosphorus, plant samples were ashed overnight at 500°C, put into solution in an acid medium and then filtered. These solutions were then made to volume with distilled water. Phosphorus content was determined with a spectrophotometer using Harris' (1978) ammmonium molybdate-ANSA method. Calcium was determined using the technique of Allen et al. (1974) EDTA titration.

STATISTICAL DESIGN

Analysis of variance was used to determine statistically significant differences. The factors included: replications, treatments, species and collection dates. Since the burns were too small to hold replicated plots within them, the three study sites themselves were used as replicates. The treatment comparison was the burned versus nonburned.

Originally, the statistical design consisted of six dates and nine species for two years, but due to sampling difficulties incurred in the first year, and laboratory constraints, the major comparison for the 1982 field season consisted of one date and five species, and the major comparison for 1983 consisted of three dates and nine species. The five species analyzed for August 22, 1982 were: aspen (POTR), serviceberry (AMAL), snowbrush (*Ceanothus velutinus*) (CEVE), and pinegrass (CARU). The next most valid test for the first field season used two dates, August 2 and 22, and two species, aspen and pinegrass, to give a preliminary relationship over time.

The second field season consisted of three dates: July 15, August 15 and September 15, and nine species. These species included the same five species as the first test plus: blue wildrye (ELGL), sticky geranium (GEVI), blue lupine (LUAR) and heart-leaf arnica (*Arnica cordifolia*) (ARCO).

To give a year-to-year comparison, the five species from August 22, 1982 were matched with the same species from August 15, 1983. Even though there was a week's difference in time, the phenological states of the plants were comperable for the two years. A comparison using aspen and pinegrass for August 2 and 22, 1982, and July 15 and August 15 1983, was also made.

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

RESULTS

1982 Field Season

Digestibility

The analysis of variance for the five species collected on August 22, 1982, showed no significant treatment effects for IVDMD for either sheep or elk rumen fluid. Only sheep had significant ($p<0.001$) site differences, with Manning Basin having the most digestible forages. Both the sheep and elk digestibilities showed significant ($p<0.001$) plant species differences. Pinegrass was generally the most digestible plant species for both animals, even though aspen in the sheep run was just as digestible (Table 1). Chokecherry was significantly less digestible than any other species in the sheep run. The rest of the shrubs were not different for either the sheep or elk runs. No treatment differences were revealed by Sheffe LSD values for individual plant species for either the elk or the sheep runs (Table 1).

Crude Protein

The analysis for crude protein showed a definite treatment effect ($p=0.05$) with the burned areas having a higher overall crude protein content (16.9%) than the nonburned areas (13.8%). The forages from Manning Basin had higher ($p<0.001$) crude protein levels than Snowdrift I or II. There was also a highly significant species effect ($p<0.001$) with the shrubs having a higher crude protein content than pinegrass, but differences among shrubs were not significant (Table 2). When the LSD was applied to the treatment x species means, all of the shrubs on the burn had significantly higher crude protein contents than those on

Table 1. Percent sheep and elk IVDMD of various forages with all three sites pooled, Aug. 22, 1982.

Species	Treatment	Trt x spp (Sheep)	Species	Trt x spp (Elk)	Species
POTR	B	54.7ab[1]	52.1bc	47.8ab	47.6a
	NB	49.4ab		47.5ab	
CEVE	B	49.1ab	48.9b	47.4ab	47.4a
	NB	48.7ab		47.5ab	
AMAL	B	50.6ab	49.4b	50.4ab	47.3a
	NB	48.2ab		44.2a	
PRVI	B	45.9ab	45.0a	47.0ab	46.1a
	NB	44.2a		45.2a	
CARU	B	51.6ab	54.1c	52.9ab	55.2b
	NB	56.5b		57.6b	

[1] Means not followed by a common letter are statistically different at alpha=0.05

Table 2. Percent crude protein in various forages with all three sites pooled, Aug. 22, 1982.

Species	Treatment	Treatment x species Means	Species Means
POTR	B	19.1e[1]	16.6b
	NB	14.1bc	
CEVE	B	18.2e	16.3b
	NB	14.4c	
AMAL	B	18.1e	16.5b
	NB	15.0cd	
PRVI	B	17.7e	16.3b
	NB	14.9cd	
CARU	B	11.4ab	10.9a
	NB	10.8a	

[1] Means not followed by a common letter are statistically different at alpha=0.05

the nonburned areas. Pinegrass showed no treatment effects.

Phosphorus

A highly significant ($p<0.01$) treatment effect was found for the influence of burning on phosphorus content of forages. There were no site differences. The nonburned areas were higher in phosphorus (0.36%) than the burned areas (0.28%). The LSD test showed that snowbrush and pinegrass were not significantly different from each other when both the burned and nonburned values were pooled, but they had significantly less phosphorus than serviceberry and chokecherry (Table 3). Aspen had an intermediate value significantly different from the other forages. When an LSD test was applied to the treatment x species means, it was found that serviceberry and chokecherry on the nonburned areas had significantly higher amounts of phosphorus than other species, burned or nonburned. The other plant species showed no significant treatment differences between burned and nonburned areas.

Calcium

Calcium content of the forages was found to be significantly higher ($p<0.005$) on the unburned areas (1.65%) than it was on the burned areas (1.31%). There were no site differences. The LSD value for pooled burned and nonburned values showed that aspen, serviceberry, and chokecherry, while not significantly different, were significantly higher in calcium than pinegrass and snowbrush (Table 4). Pinegrass had the lowest calcium contents. When the LSD test was applied to the treatment x species means, only chokecherry showed a significant difference between burned and unburned areas (Table 4).

Table 3. Percent phosphorus in various forages with all three sites pooled, Aug. 22, 1982.

Species	Treatment	Treatment x species Means	Species Means
POTR	B	.32cd[1]	.30b
	NB	.28bc	
CEVE	B	.23abc	.19a
	NB	.14a	
AMAL	B	.39d	.48c
	NB	.57e	
PRVI	B	.29bcd	.45c
	NB	.60e	
CARU	B	.19ab	.19a
	NB	.20ab	

[1]Means not followed by a common letter are statistically different at alpha=0.05

Table 4. Percent calcium in various forages with all three sites pooled, Aug. 22, 1982

Species	Treatment	Treatment x species Means	Species Means
POTR	B	1.66c[1]	1.77c
	NB	1.87cd	
CEVE	B	0.93ab	1.07b
	NB	1.20b	
AMAL	B	1.75cd	1.91c
	NB	2.07de	
PRVI	B	1.64c	2.00c
	NB	2.37e	
CARU	B	0.55a	0.64a
	NB	0.73a	

[1]Means not followed by a common letter are statistically different at alpha=0.05

Calcium/Phosphorus Ratio

The Ca/P ratios showed a significantly higher ($p=0.05$) treatment mean for the nonburned areas (5.4) than the burned areas (4.5). There were no site differences. There was also a highly significant ($p<0.005$) species effect with aspen and snowbrush having the highest ratios and pinegrass the lowest (Table 5). When the LSD test was applied to the treatment x species means, only snowbrush had a significantly higher Ca/P ratio on the nonburned areas.

Table 5. Ca/P ratios for various forages with all three sites pooled, Aug. 22, 1982.

Species	Treatment	Treatment x species Means	Species Means
POTR	B	5.2bcd [1]	6.1c [2]
	NB	7.1de	
CEVE	B	4.0abc	6.2c
	NB	8.4e	
AMAL	B	4.6abc	4.2ab
	NB	3.6ab	
PRVI	B	5.8cd	5.1c ?
	NB	4.3abc	
CARU	B	2.9a	3.2a
	NB	3.6ab	

[1] Means not followed by a common letter are statistically different at alpha=0.05

[2] Ca/P ratios may not agree with %Ca divided by %P because of rounding errors

Dates

Aspen and pinegrass from August 2 and 22 were analyzed for the second-most-valid test of the 1982 field season. The four-factor analysis of variance showed no effect of burning on digestibility for sheep IVDMD treatment means. Elk IVDMD, however, did show a treatment effect ($p<0.01$) with the samples from the burned areas (55.6%) being more digestible than the nonburned areas (51.2%). The major difference in the two runs was in the way the aspen was digested on August 2. The nonburned areas had approximately the same digestibilities for both sheep and elk, but the burned aspen digestibilities were almost twenty points lower for the sheep than it was for the elk (Table 6). Thus, no treatment differences were noted for aspen for sheep on August 2, but ~~but~~ they were for elk. Pinegrass showed no significant treatment difference for either sheep or elk IVDMD.

There was no significant date effect for the sheep, but there was for the elk ($p<0.01$). The aspen from the burn was more digestible on August 2 than it was on August 22. The nonburned plants were similar (Table 6).

There was a large treatment difference ($p<0.001$) for crude protein (Table 6). Aspen on the burned areas had a higher amount than the aspen on the nonburned areas (Table 6). There was also a significant ($p<0.005$) species effect with aspen on the burned areas having significantly more crude protein than pinegrass on any date or treatment. There was no date difference on either the burned or nonburned areas for aspen or pinegrass (Table 6).

Treatment means for phosphorus showed a significantly ($p<0.001$) higher amount on the burned areas (0.28%) than on the nonburned areas (0.23%). There was a significant species difference ($p<0.01$) with

Table 6. Treatment x species means for all analyses of aspen and pinegrass, Aug. 2 and Aug. 22, 1982, all three sites pooled.

SPECIES	DATE	TREATMENT	%SHEEP IVDMD	%ELK IVDMD	%CP	%P	%Ca	CA/P[2]
POTR	AUG 2	B	43.5a[1]	61.8d	21.7d	.39d	1.47b	4.0ab
		NB	50.3a	51.8abc	15.8c	.24ab	1.78c	7.7d
	AUG 22	B	57.9ab	48.7ab	19.2d	.32cd	1.88c	5.6bc
		NB	53.5a	48.3a	14.2bc	.27b	1.86c	7.1cd
CARU	AUG 2	B	53.7a	54.7abc	13.5abc	.23ab	0.54a	2.3a
		NB	52.7a	48.9ab	10.3a	.23ab	0.79a	3.4a
	AUG 22	B	54.6a	57.1cd	11.47ab	.19a	0.54a	2.9a
		NB	56.8ab	55.9bcd	10.48a	.20ab	0.74a	3.6a

[1] Means not followed by a common letter are statistically different at alpha=0.05

[2] Ca/P ratios may not agree with % Ca divided by % P because of rounding errors

aspen on the burned areas on both dates having a higher phosphorus content than pinegrass on any date or treatment (Table 6). There were no significant date differences for either aspen or pinegrass. When the LSD was applied to treatment x species x date means, aspen was significantly higher in phosphorus on the burned areas on both August 2 and 22 than it was on the nonburned areas (Table 6).

Calcium occurred in higher amounts ($p<0.001$) on nonburned areas (1.29%) than on burned areas (1.09%). Aspen had higher amounts ($p<0.001$) of calcium than pinegrass on any date or treatment (Table 6). The only date difference occurred when aspen increased in calcium on the burned areas from August 2 to August 22.

The calcium/phosphorus ratios were significantly ($p<0.005$) lower on the burned areas (3.7) than on nonburned areas (5.5). There was a species effect ($p<0.0001$) with pinegrass having lower ratios than aspen, except on the burned areas August 2. Aspen had significantly higher Ca/P ratios on the nonburned areas August 2 than it did on the burned areas. There were no date differences for either aspen or pinegrass (Table 6). There were no site differences, either.

1983 Field Season

Digestibility

Sheep digestibilities showed a treatment effect with the nonburned areas being slightly but significantly ($p<0.05$) higher (61.5%) overall than the burned areas (59.9%). Elk digestibilities were also significantly ($p<0.05$) higher on the nonburned areas (61.5%) than on the burned areas (59.7%). There were no site differences for either the sheep or the elk digestibilities. There was no date effect for elk, but sheep showed a highly significant ($p<0.001$) effect with July 15 being higher in digestibility than August or September (Table 7). The forbs, while not significantly different from each other, had higher sheep and elk digestiblities than the grasses or shrubs, which were not different (Table 8).

Table 7. Date means for all analyses with treatments and all three sites pooled, 1983.

Date	%Sheep IVDMD	%Elk IVDMD	%CP	%Ca	%P	Ca/P
JULY 15	65.9 [1]	60.2	16.3 [1]	1.28 [1]	.33 [1]	3.9 [1,2]
AUG. 15	58.6	61.6	12.5	1.57	.27	5.8
SEPT.15	57.5	60.1	10.9	1.70	.29	5.9

[1] Levels of significance are alpha=0.001.

[2] Ca/P ratios may not agree with %Ca divided by %P because of rounding errors

On a species by species basis for the sheep, all of the shrubs except chokecherry showed a v-shaped date configuration (Figure 2).

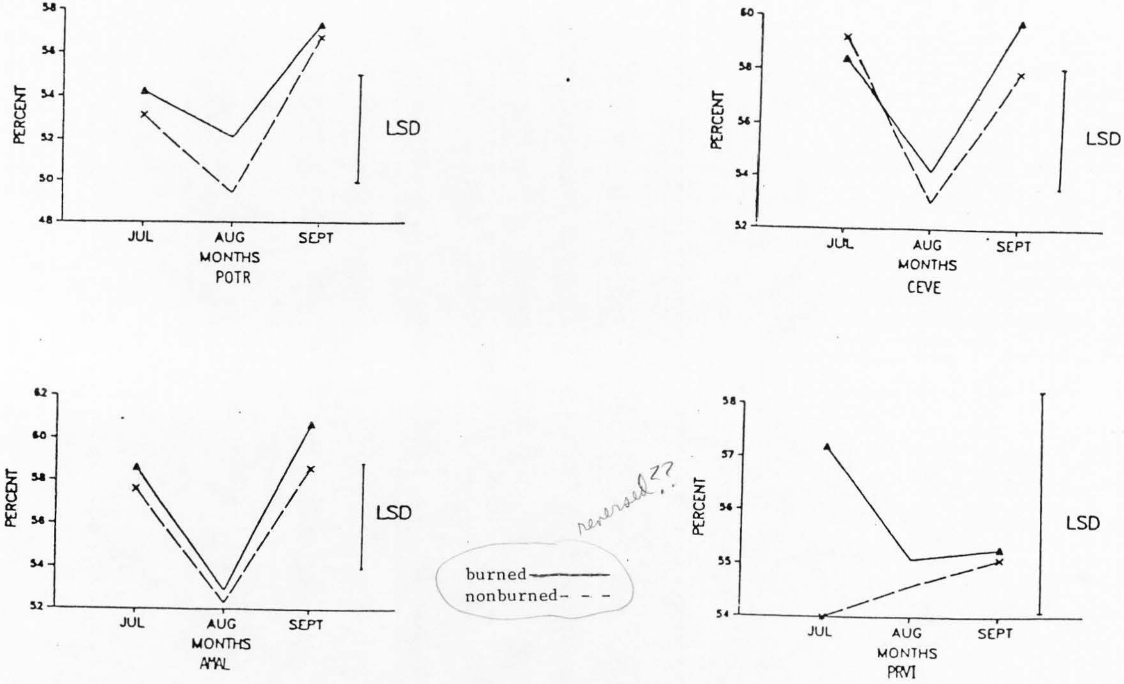


Figure 2. Percent sheep IVDMD for shrubs on three dates, all three sites pooled, 1983

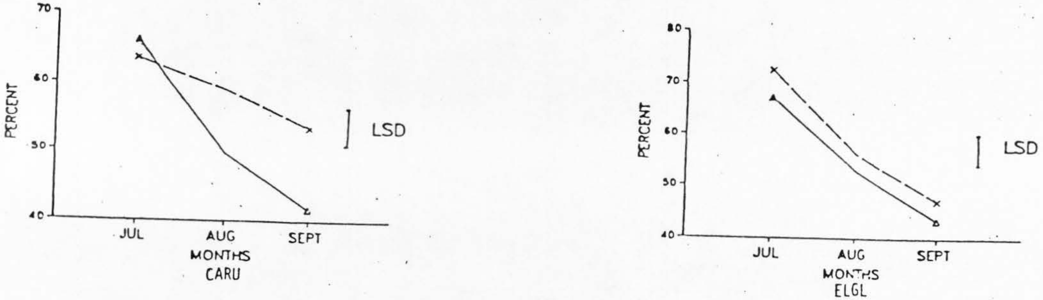
Table 8. Species means for all analyses with treatments and all three dates and sites pooled, 1983

Species	%Sheep IVDMD	%Elk IVDMD	%CP	%Ca	%P	Ca/P
Shrubs						
POTR	53.8a[1]	55.5ab	15.4cd	1.45	.26abc	5.6bc[2]
CEVE	57.0b	57.8b	14.2bc	1.28	.21a	6.0bc
AMAL	56.7ab	59.0b	14.6c	1.58	.43d	4.3a
PRVI	55.2ab	58.7b	15.0cd	1.92	.36cd	5.3ab
Grasses						
CARU	55.6ab	52.5a	10.5a	.81	.21a	3.8a
ELGL	56.6ab	55.5ab	13.1b	1.11	.22a	5.1ab
Forbs						
GEVI	70.4cd	69.0c	13.1b	1.98	.39d	5.1ab
LUAR	68.9c	67.7c	16.0d	1.55	.24ab	6.5cd
ARCO	72.0d	69.9c	9.7a	1.99	.35bcd	5.7bc

[1] Means not followed by a common letter are statistically different at alpha=0.05

[2] Ca/P ratios may not agree with %Ca divided by %P because of rounding errors

Snowbrush and serviceberry were significantly lower in digestibility for both the burned and nonburned areas on August 15. Aspen exhibited this reduction on the nonburned, but on the burn it was not significant. Both of the grasses showed a sharp decline in digestibility for sheep throughout the three dates, but the nonburned areas declined less than the burned areas (Figure 3). Lupine and arnica



burned————
nonburned- - -

Figure 3. Percent sheep IVDMD for grasses on three dates, all three sites pooled, 1983

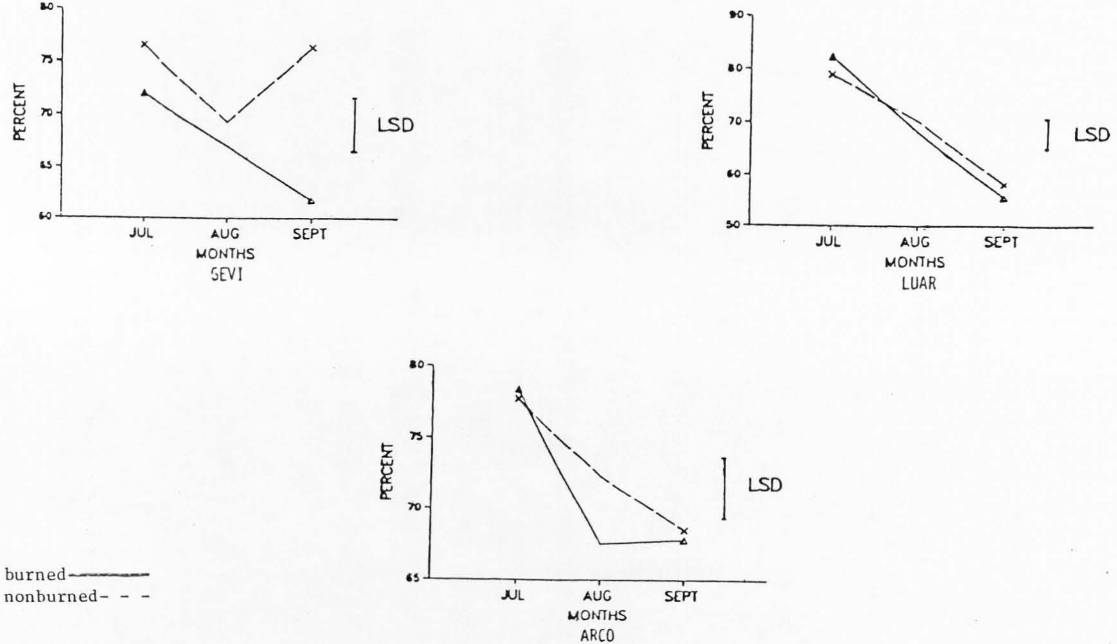


Figure 4. Percent sheep IVDMD for forbs on three dates, all three sites pooled, 1983

digestibilities declined throughout the season (Figure 4). Geranium digestibility declined on the burn, but the nonburned plants increased in digestibility from August to September.

Crude Protein

The nonburned areas (13.7%)had higher ($p<0.01$) amounts of crude protein than the burned areas (12.8%). There were no site differences for crude protein in 1982. There was also a significant date effect ($p<0.0001$) with July being the highest in crude protein and September the lowest (Table 7). There was a significant species effect, with pinegrass and arnica having significantly lower crude protein contents than the other species (Table 8). All of the shrubs were statistically the same on both the burned and nonburned areas throughout the summer, except snowbrush which was lower on the burned areas in July (Figure 5). Wildrye, geranium and arnica also showed no treatment effects for any date (Figures 6 and 7). The treatment effect came mainly from the lower crude protein content of pinegrass which was lower on the burned areas than it was on the nonburned areas on all dates (Figure 6). Lupine, however, had similar crude protein contents for July, but by August had significantly higher contents on the burned than on the unburned areas.

Phosphorus

Phosphorus contents were higher ($p<0.0001$) on the nonburned areas (0.34%) than on the burned areas (0.25%). There was a site difference with the forages from Manning Basin having higher ($p<0.001$) amounts of phosphorus. There was no difference in phosphorus content between the

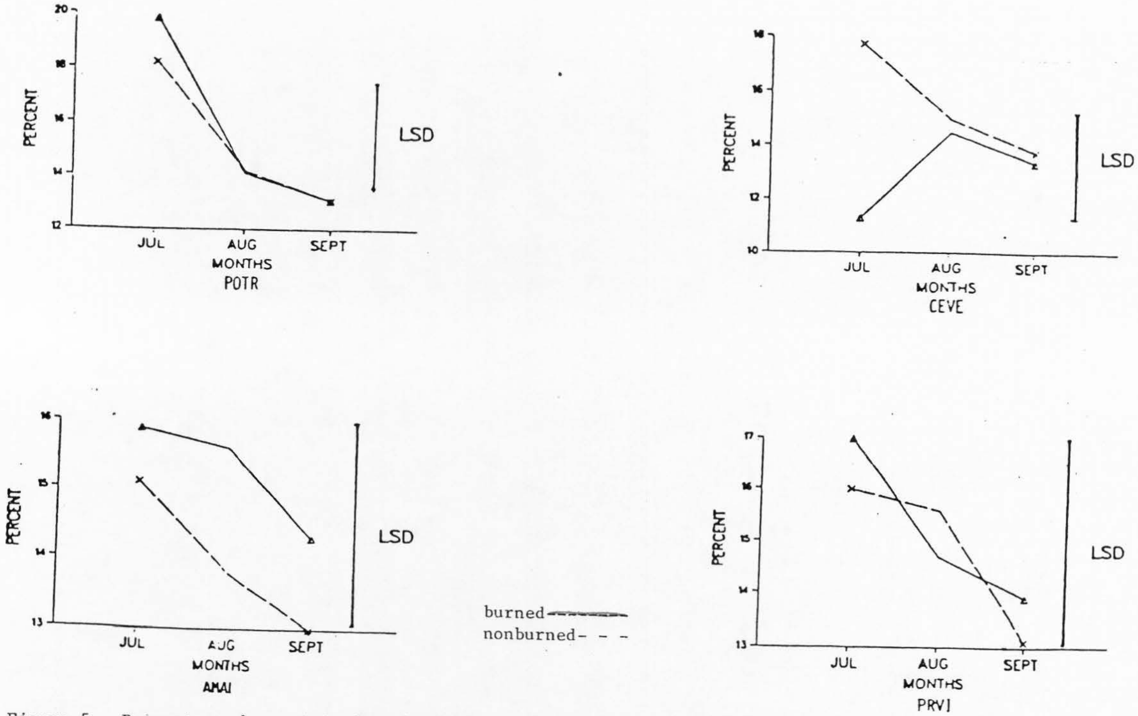
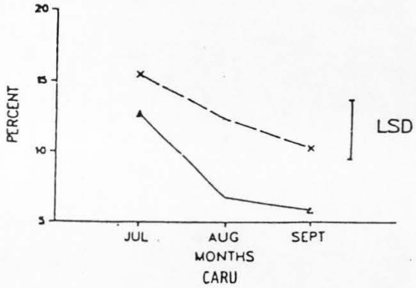
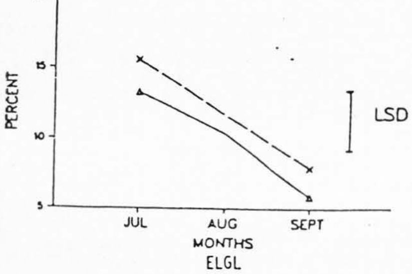


Figure 5. Percent crude protein for shrubs on three dates, all three sites pooled, 1983





burned———
nonburned- - -

Figure 6. Percent crude protein for grasses on three dates, all three sites pooled, 1983

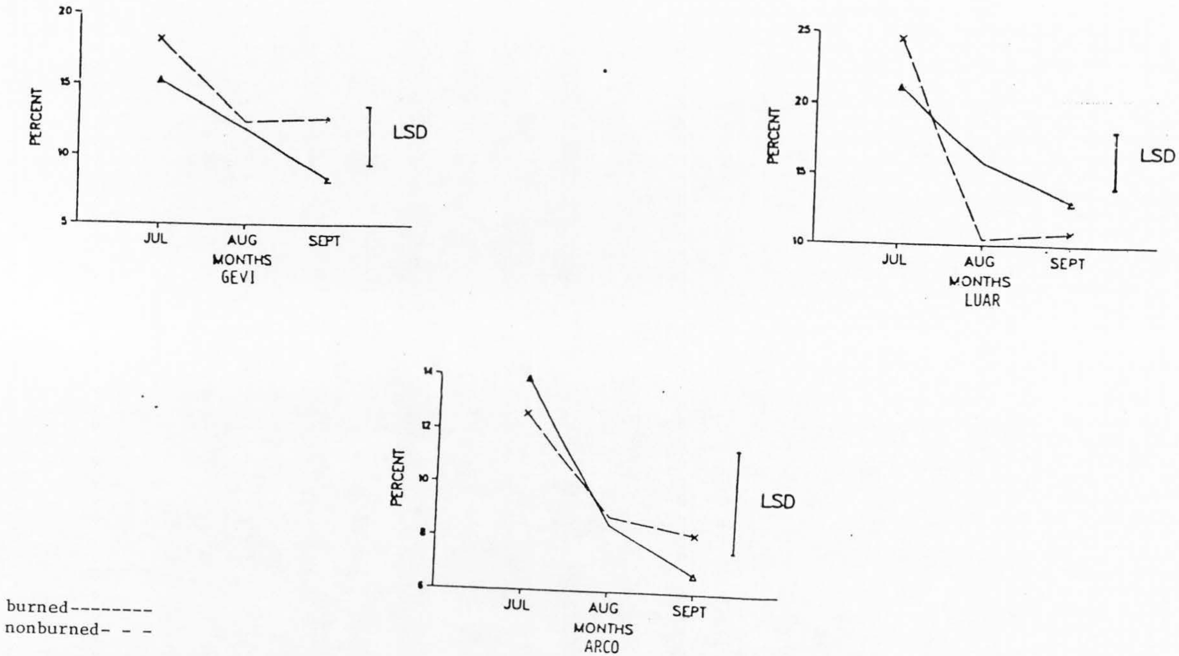


Figure 7. Percent crude protein for forbs on three dates, all three sites pooled, 1983

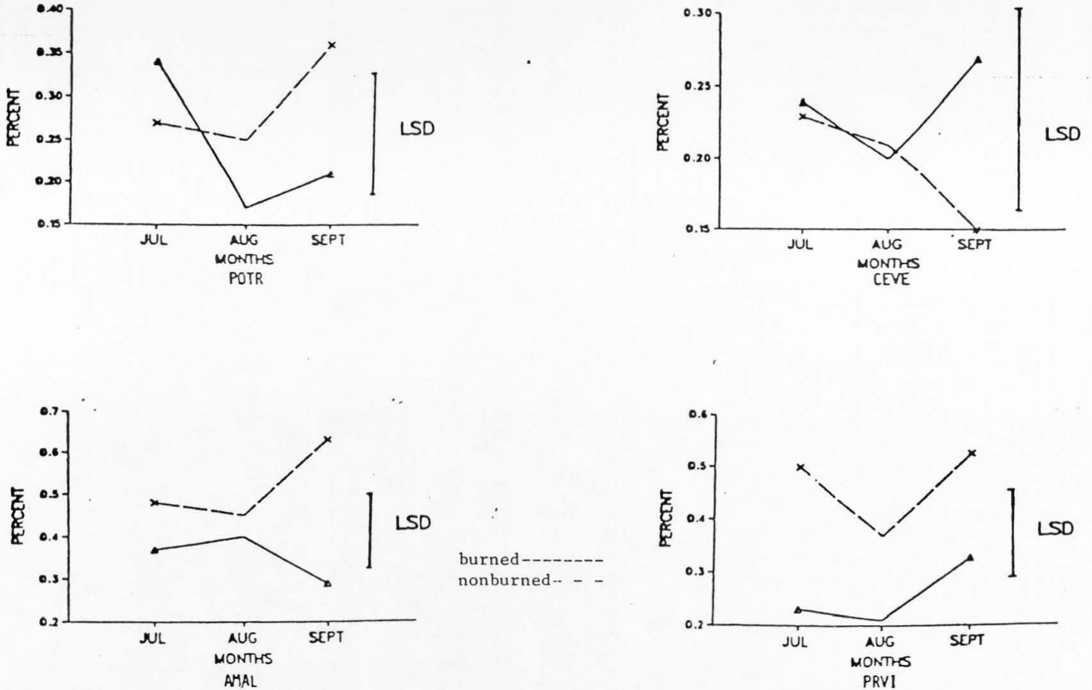
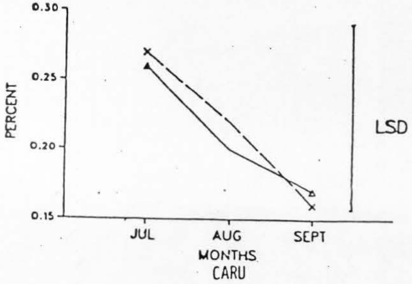
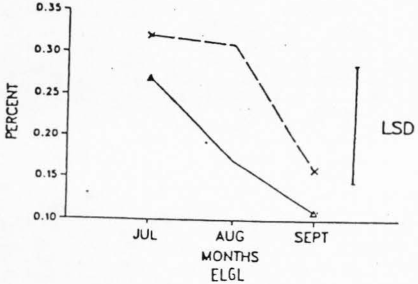


Figure 8. Percent phosphorus for shrubs on three dates, all three sites pooled, 1983





burned--------
nonburned- - -

Figure 9. Percent phosphorus for grasses on three dates, all three sites pooled, 1983

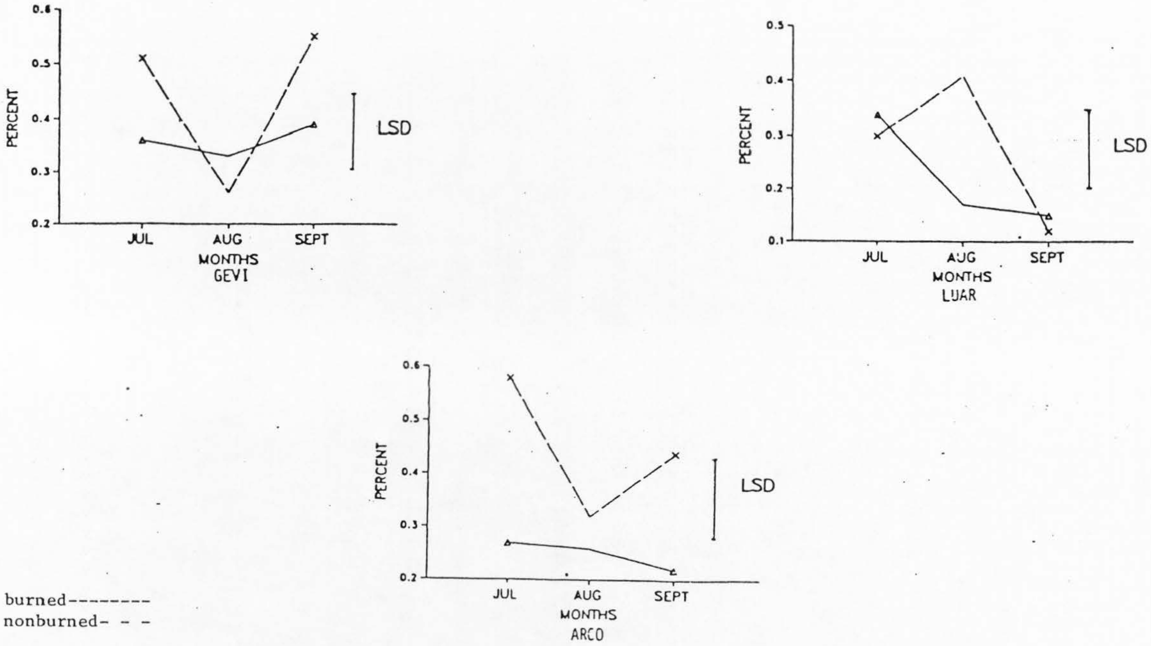


Figure 10. Percent phosphorus for forbs on three dates, all three sites pooled, 1983

shrubs and forbs. There was a significant date difference ($p<0.001$) with forages in July being higher in phosphorus than those in August and September (Table 7). Most of the shrubs and forbs exhibited a v-shaped date configuration for the nonburned areas (Figures 8 and 10). Phosphorus contents for chokecherry, geranium and arnica in July and September were not different but were significantly lower in August (Figures 8 and 10). Phosphorus contents in July and August were not significantly different for aspen and serviceberry, but the amount of phosphorus in the plants in September was significantly higher than in July or August. For lupine, however, phosphorus levels in July and August were not significantly different but September levels were lower (Figure 10). There was also a significant species effect ($p<0.001$) with the grasses having the least phosphorus (Table 8).

Calcium

There were no differences in calcium contents between burned and nonburned areas. There were no differences among sites. Calcium contentsin September were significantly ($p<0.001$) higher than in July (Table 7). The grasses were lower in calcium than the shrubs and forbs, which were not different (Table 8).

Calcium/phosphorus ratio

Burned areas (5.8) had higher ($p<0.0001$) Ca/P ratios than nonburned areas (5.0). There were no site differences. There was also a species effect with lupine having the highest ratio and pinegrass the lowest (Table 8). July had significantly ($p<0.001$) lower ratios than either August or September (Table 7).

1982 vs. 1983

Digestibility

Both the sheep and elk IVDMD analyses had highly significant year variations ($p<0.0001$). The forages collected the second year were more digestible. For the sheep run, this variation came from chokecherry. Both burned and nonburned samples were significantly higher in digestibility the second year (Table 9). Most of the other plants had numerically higher digestiblities the second year, but were not statistically significant. For elk, however, all samples except pinegrass were higher in digestibility the second year (Table 10).

Table 9. Sheep IVDMD for Aug. 22, 1982 and Aug. 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	54.7de [1]	52.1cde
	NB	49.4bcd	49.3bcd
CEVE	B	49.1bcd	54.1de
	NB	48.7abc	53.0cde
AMAL	B	50.6cd	52.9cde
	NB	48.2abc	52.2cde
PRVI	B	45.9ab	55.1ef
	NB	44.2a	54.5de
CARU	B	51.6cd	49.6bcd
	NB	56.5ef	59.1f

[1] Means not followed by a common letter are statistically different at alpha=0.05

Table 10. Elk IVDMD for Aug. 22, 1982 and Aug. 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	47.8abc[1]	56.9ef
	NB	47.5abc	55.2de
CEVE	B	47.4abc	61.9f
	NB	47.5abc	60.9f
AMAL	B	50.4bcd	57.0ef
	NB	44.2a	56.6ef
PRVI	B	47.0abc	59.6f
	NB	45.2ab	58.7d
CARU	B	52.9de	46.7ab
	NB	57.6ef	56.2ef

[1] Means not followed by a common letter are statistically different at alpha=0.05

Crude Protein

Crude protein contents of forages collected the second year were significantly lower ($p<0.001$) than those collected the first year. All of the species had reduced crude protein levels the second year on the burned areas except serviceberry which was numerically lower, but not significantly (Table 11). None of the crude protein levels of the shrubs on the burned areas the second year were different from the nonburned areas. None of the nonburned samples exhibited a year difference. Pinegrass, though, was significantly lower in crude protein on the burned areas the second year than it was on the nonburned areas either year (Table 11).

Table 11. Percent crude protein for Aug. 22, 1982 and Aug. 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	19.1h[1]	14.1cdef
	NB	14.1def	14.1def
CEVE	B	18.2gh	14.5def
	NB	14.4def	15.0ef
AMAL	B	18.1gh	15.6efg
	NB	15.0ef	13.8cde
PRVI	B	17.7gh	14.6def
	NB	14.9ef	15.6efg
CARU	B	11.4bc	6.8a
	NB	10.4b	12.2bcd

[1]Means not followed by a common letter are statistically different at alpha=0.05.

Phosphorus

Phosphorus levels were significantly higher ($p<0.02$) the first year than the second. Aspen on the burned areas and and chokecherry on the nonburned areas, however, were the only samples that showed significant changes in phosphorus content. The other shrubs were numerically but not significantly, lower in phosphorus content in 1983.

Calcium

There were no year-to-year differences in calcium levels (Table 13).

Calcium/phosphorus ratio

The Ca/P ratios of the forages were lower ($p<0.05$) in 1982 than in 1983. This variation came mainly from snowbrush on the burned areas and chokecherry on both the burned and nonburned areas (Table 14).

Table 12. Percent phosphorus for Aug. 22, 1982 and Aug 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	.32bcde[1]	.17a
	NB	.28abcd	.25abcd
CEVE	B	.23abc	.20ab
	NB	.14a	.21ab
AMAL	B	.39de	.39de
	NB	.57fg	.45fe
PRVI	B	.29bcd	.21a
	NB	.60g	.37cde
CARU	B	.19ab	.20ab
	NB	.20a	.21ab

[1] Means not followed by a common letter are statistically different at alpha=0.05

Table 13. Percent calcium for Aug. 22, 1982 and Aug. 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	1.66[1]	1.18
	NB	1.87	1.67
CEVE	B	.93	1.34
	NB	1.20	1.72
AMAL	B	1.75	1.36
	NB	2.07	1.42
PRVI	B	1.64	1.56
	NB	2.37	1.90
CARU	B	.55	.89
	NB	.73	1.27

[1] The Sheffe LSD value of 2.5 was used to test for statistical differences at alpha=0.05

Table 14. Ca/P ratios for Aug. 22, 1982 and Aug. 15, 1983, all three sites pooled.

Species	Treatment	1982	1983
POTR	B	5.2abc [1]	6.3bcd
	NB	7.1cd	6.9cd
CEVE	B	4.0ab	6.1bcd
	NB	8.4de	7.0cd
AMAL	B	4.7abc	4.9abc
	NB	3.6ab	4.6abc
PRVI	B	5.8bcd	9.7e
	NB	4.3ab	6.6cd
CARU	B	2.9a	2.8a
	NB	3.6a	3.0a

[1] Means not followed by a common letter are statistically different at alpha=0.05.

[2] Ca/P ratios may not agree with %Ca divided by %P because of rounding error

Dates/years comparison

The analysis of variance for aspen and pinegrass Aug. 2 and 22 1982, and July 15 and Aug. 15 1983, showed that sheep digestibilities increased from 1982 to 1983 for both aspen and pinegrass on the burned areas only for the first date (Table 15). Pinegrass also increased in digestibility the first date on the nonburned areas. There were no other significant differences.

Sheffe LSD values were calculated for elk digestibilities (Table 16), phosphorus (Table 17) and crude protein contents (Table 18), but no significant differences were found.

Calcium contents decreased significantly ($p<0.001$) for aspen on the nonburned areas on the first date and for aspen on the burned areas the second date. No other samples had year-to-year variations (Table 19).

Table 15. Sheep IVDMD for aspen and pinegrass, Aug. 2 (1) and 22 (2), 1982 and July 15 (1) and Aug. 15 (2), 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	43.5a [1]	54.1bc
		NB	50.0ab	53.0bc
POTR	2	B	57.8bcde	52.1abc
		NB	53.5bc	49.3sb
CARU	1	B	53.7bc	66.1e
		NB	52.6bc	63.5de
CARU	2	B	54.6bc	49.6ab
		NB	56.7bcd	59.1cde

[1]Means not followed by a common letter are statistically different at alpha=0.05

Table 16. Elk IVDMD for aspen and pinegrass, Aug. 2 (1) and 22 (2), 1982 and July 15 (1) and Aug. 15 (2), 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	61.9 [1]	51.3
		NB	51.8	53.1
POTR	2	B	48.7	56.9
		NB	48.3	55.2
CARU	1	B	54.6	54.1
		NB	48.8	55.1
CARU	2	B	57.0	46.7
		NB	55.8	56.2

[1]The Sheffe LSD value of 14.2 was used to test for year-to-year differences at alpha=0.05

Table 17. Percent crude protein for aspen and pinegrass Aug. 2 (1), and 22 (2) 1982, July 15 (1) and Aug. 15 (2) 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	21.7 [1]	19.7
		NB	15.7	18.1
POTR	2	B	19.1	14.1
		NB	14.1	14.1
CARU	1	B	13.4	12.7
		NB	10.3	15.5
CARU	2	B	11.4	6.8
		NB	10.4	12.2

[1] The Sheffe LSD value of 7.2 was used to test for year-to-year differences at alpha=0.05

Table 18. Percent phosphorus of aspen and pinegrass Aug. 2 (1) and 22 (2), July 15 (1) and Aug. 22 (2), 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	.39 [1]	.34
		NB	.24	.27
POTR	2	B	.32	.20
		NB	.27	.22
CARU	1	B	.23	.26
		NB	.23	.27
CARU	2	B	.19	.16
		NB	.20	.24

[1] The Sheffe LSD value of 0.14 was used to test for year-to-year differences at alpha=0.05

Table 19. Percent calcium for aspen and pinegrass Aug. 2 (1) and 22 (2), July 15 (1) and Aug. 15 (2), 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	1.46bc [1]	1.23b
		NB	1.78cd	1.28b
POTR	2	B	1.80cd	1.30b
		NB	1.86d	1.56bcd
CARU	1	B	.54a	.61a
		NB	.79a	.70a
CARU	2	B	.58a	.48a
		NB	.74a	.76a

[1] Means not followed by a common letter are statistically different at alpha=0.05

Table 20. Ca/P ratios for aspen and pinegrass Aug. 2 (1) and 22 (2), July 15 (1) and Aug. 15 (2), 1983.

Species	Date	Treatment	1982	1983
POTR	1	B	4.0 [1]	3.5
		NB	7.7	4.7
POTR	2	B	5.6	6.3
		NB	7.1	6.9
CARU	1	B	2.3	2.3
		NB	3.4	2.6
CARU	2	B	2.9	2.9
		NB	3.6	3.1

[1] The Sheffe LSD value of 2 was used to test for year-to-year differences at alpha=0.05

DISCUSSION

Certain precautions should be exercised in the interpretations placed on chemical analyses of forage plants for a number of reasons: (1) statistical significance does not necessarily mean physiological significance to the animals concerned and vice versa; (2) plant parts analyzed may not be in the same proportions or kinds as taken by animals in their selective feeding behavior; (3) analyzing species singly gives only a partial reflection of the total mixture of plant species normally consumed; and (4) laboratory results may be in error (Dietz and Curnow 1966). Thus, while this study gives some indication of plant response to burning, it is only one aspect of the complex plant-animal-soil interface.

The phenological stages of the plants were similar on the burned and nonburned areas. Aspen communities are mesic so the forbs collected bloomed throughout the entire season. Thus several different phenological stages overlapped within and between the burned and nonburned areas. Pinegrass had few flower stalks in the nonburned areas and many in the burned areas, but the phenological stages were similar. The shrubs did not exhibit any reproduction on the burned areas during either summer. So, in this study, dates are used instead of phenological stages as a comparative index.

Overall, there was little improvement in forage quality from burning, with some reduction in quality the second year. Aspen on August 2, 1982 showed improved Ca/P ratios, elk digestibilities, crude protein and phosphorus levels and decreased calcium content on the burned versus the nonburned areas. By August 22, only the Ca/P ratios and crude protein levels were improved on burned sites. All of the shrubs on August 22 had higher crude protein levels, but only serviceberry had higher phosphorus levels. There were no improvements in quality in 1983 for the shrubs or the forbs. This lack of difference after an initial improvement in forage quality for the shrubs could be due to the change in growth form of the plants from the burned areas. In early August, 1982, most of the shrubs on the burned areas were less than a foot tall, had few stems and larger leaves than the nonburned areas. By late August, there was secondary branching and the plants were up to 2 feet in height. In 1983, the shrubs were 3-5 feet in height, with more branches and smaller leaves. Thus the shrubs in early August the first year after the fire had lower stem-to-leaf ratios than they did in late August the same year or in the second year after the fire. This could have been the reasons for similarities in nutrient contents between burned and nonburned areas.

The improvement in crude protein, however short-lived, is very important to the ruminant. The higher protein levels allow the animals to obtain a highly nutritious diet when it is needed the most--during lactation, rapid body growth of fawns, and increasing body fat stores for the winter. Several of the analyses performed resulted in no statistical differences, but where there was a numerical difference, it may be biologically significant to the animal. An increase of a few points in any analysis may mean the difference of good health and condition or marginal health and condition. Conversely, the internal variation in the statistical analyses may be due to variability in the forages present on the site so that numerical differences may mean nothing to the animal.

Phosphorus contents of forages showed a beneficial treatment effect in only one analysis. Aspen on August 2, 1982 had higher levels of phosphorus on the burned areas than on the nonburned areas. All of the other analyses showed either lower levels of phosphorus for the burned samples or no difference. There was not a lot of change, however. Swank (1958) also found lower phosphorus contents of forages on burned areas than unburned areas for 9-month, and 3-, 5- and 8-year-old burns in the Arizona chaparral. Meenely and Schemnitz (1981) found no differences in phosphorus levels of forages on 3-year-old burns in New Mexico. Halls et al. (1952) also found no differences in phosphorus levels of deer's tongue (*Trilisa oderatissima*) after burning in central Florida.

Calcium was generally lower on the burned areas than it was on the nonburned areas. Lay (1957) also reported lower calcium contents of plants on burned areas than unburned areas in an east Texas pine forest. This would be of benefit to the animal since Ca/P ratios are also lower on the burned areas, and thus the possibility of interference with phosphorus metabolism would be lessened.

The major aspect of the Ca/P ratios in this study, is that, with the exception of the grasses, all are much higher than the optimal ratios suggested for ruminants--1:2 or 1:2 (Dietz 1965). Urness (1973), suggests that Ca/P ratios of 1:2-2:1 are excellent, 2:1-3:1 are good, 3:1-5:1 are fair and those larger than 5:1 are poor. He also stated, however, that these are general standards and undue emphasis should not be placed on single factors. For example, plants poor in phosphorus may be good sources of protein, energy, or some other factor. It is the collective intake of particular nutrients in the total diet that is critical. Thus the Ca/P ratios are only comparitive measures which still need to be researched. Burning, however, did seem to improve these ratios by lowering them, at least for the first year. On August 2 and 22, 1982 for aspen and pinegrass, the burned areas were higher in phosphorus and lower in calcium than the nonburned areas so the Ca/P ratios were higher for the nonburned areas. On August 22, for the five species tested, calcium levels on the nonburned areas were higher than on the burned areas and the phosphorus levels were higher on the nonburned areas. The phosphorus levels were not high enough to negate the higher amount of calcium, so the Ca/P ratios were higher for the nonburned areas for that date. In 1983, calcium levels were the same on the burned and nonburned areas, but the phosphorus levels on the nonburned areas were higher for the forages collected, so the Ca/P ratios were lower on the nonburned areas. The year-to-year comparison for the five species had the same calcium levels on the burned areas as on the nonburned areas, but phosphorus levels were higher in 1982, so the Ca/P ratios were higher in 1983. The two date x two year comparison for aspen and pinegrass showed no change in phosphorus levels, but calcium levels were significantly lower in 1983. This change was not enough to produce a significant difference in Ca/P ratios between years.

On a species basis, pinegrass showed no differences the first year for any nutritional test and by the next year the burned areas showed significant decreases in digestibilities and crude protein when compared with the nonburned areas. This decrease in quality could be due to a number of factors. The average maximum soil surface temperatures on the burned sites may be 3°-16°C higher than on comparable unburned areas (Ahlgren 1974). In a progress report by Brown et al. (1983), soil temperature changes between burned and nonburned areas were in excess of 20°C in July 1982 on the Manning Basin site. Increased soil temperatures hasten the development of roots and shoots on burned areas, speed decomposition, and promote the activity of soil microorganisms (Spurr and Barnes 1977).

A number of morphological and physiological changes may occur in plants as a result of burning, and may help explain why pinegrass showed reduced levels of nutrients when plants from the burned areas were compared to those of the nonburned areas. The removal of plant tops by fire triggers latent primordial regions to initiate new growth. Growth is produced, sometimes very rapidly (Hopkins 1963, Lewis 1964). Several researchers found the vegetative reproduction of perennial species on most sites occurs more rapidly and vigorously after burning than growth on unburned sites (Vogl 1965, Old 1969, Ralston and Dix 1966, Wright 1969, Hadley 1970). This impressive change in vigor of plants may be caused by the increased uptake of nutrients (Ahlgren and Ahlgren 1960, Komarek 1967, Vogl 1969, Hayes 1970), which are more available on burned areas.

Shoots produced after a fire have been found to be stiffer and more erect than ordinary shoots (McCalla 1943, O'Connor and Powell 1963). Increased numbers of grass and forb flowers are usually stimulated by burning (Lemon 1949,1968; Curtis and Partch 1950;

Ehrenreich and Ackman 1963; Parrot 1967; Lloyd 1972). Weaver (1974) noticed that burning seemed to greatly stimulate growth of pinegrass and in the summer following burns seedheads of this species occurred by the countless millions. Brown et al. (1983), found that the grass component on the severely burned areas of Manning Basin not only produced more biomass, but uniformly flowered and produced a seed crop as well. Crane et al. (1983) noted that pinegrass maintained itself in shade and only produced seed in forest openings. They also noticed profuse blooming of pinegrass for several seasons after a fire.

This rapid maturation process, and subsequent proliferation of seedheads, causes the translocation of nutrients and soluble carbohydrates from the leaves to the inflorescence (Chapin and Van Cleve 1978, Van Soest 1982). This translocation, along with increased stem-to-leaf ratios from the many seed stalks cause a dilution of nutrients by increased cell wall material (Van Soest 1982), could have been the reason for decreased quality for pinegrass on the burned areas. These changes are consistent with Wilson's (1982) review of the effects of nitrogen fertilizer on dry matter digestibility. The increased soil microbiological activity and reduction in competition from other plants on burned areas seems to have the same detrimental results on digestibility as the use of nitrogen fetilizer. The nonburned plants have to compete for the nutrients available on the site and thus grow for a longer time before accumulating sufficient reserves for reproduction (Chapin and Van Cleve 1968). Therefore their forage quality is preserved for a longer time.

Flowering in forbs 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 the grasses, even though their phenology was similar.

Very few studies report decreases in forage quality similar to this study. Stransky and Harlow (1981) could not find any study showing deleterious effects of burning on crude protein. Asherin (1973) however, found reduced levels of crude protein in redstem ceanothus (Ceanothus sanguineus) and increased levels of crude fiber in mountain maple (Acer glabrum) on the burned areas in Idaho. Many researchers that found improvements in nutrient levels due to burning sampled the vegetation immediately after a fire to analyze early regrowth. One of the problems with this is, the nonburned areas may be more advanced phenologically than the burned areas, especially if the burn occurred in the spring. Therefore, the nonburned areas would have older vegetation that is less nutritious than the vegetation coming up on the burned areas (Stransky and Harlow 1981).

In the aspen type, prescribed fires usually occur in the fall immediately before snowfall, so there is little chance for regrowth that year. In the particular area of this study, the snowpack was heavy and lasted well into the summer and the grasses and forbs on both the burned and nonburned areas had to completely grow after being buried under several feet of snow. Thus,the plants on this study are more phenologically similar than those of other studies, and the effects of burning are less obvious.

The question of accepting or rejecting the null hypotheses is complex. On the basis of my results, I would reject all of the hypotheses. The first hypothesis, that nitrogen, calcium and phosphorus levels do not differ significantly in the same forages on burned and adjacent unburned aspen sites, was proven wrong several times in 1982 for almost all of the species. In 1983, pinegrass had significant decreases in nutrient levels, even though the shrubs and forbs had few differences between burned and nonburned areas. The second null hypothesis, that digestibilities do not differ in forages from burned and nonburned areas, was also proven wrong. The first year there was an improvement for aspen and the second year pinegrass had decreased digestibilities. Thus, I would reject the null hypotheses because differences do exist, even though this is not true for every species in every analyses.

It is hard to interpret some of the results based on the little that is known about nutrient cycling within a plant after a burn. Perhaps the v-shaped configurations for phosphorus and sheep IVDMD the second year (Figures 2-4 and 8-10) were caused by regrowth from heavy rains that occurred the week of August 15, 1983. This was not quantified, however. I could not find any published reasearch supporting these observations. Most, such as Dietz (1972), found that shrubs decline in quality throughout the season. The inconsistencies in site differences are also difficult to interpret due to the many edaphic, climatic and genetic factors that affect the morphology and metabolism of plants. It is equally hard to interpret the differences in the sheep and elk digestibilities. Many factors could be involved including differences in the way the animals digest certain compounds in the samples. Brooks and Urness (1984) however, stated that there is no statistical difference in the way rumen fluid from various animal sources digests the same plant material. Perhaps these differences are just a result of differences in the standardized diets, individual animal variation, differences in fluid collection, or not enough samples for a more sensitive statistical test. Differences in rumen inocula collection could have been the reason for the increased elk IVDMD from 1982 to 1983. Only chokecherry on both the burned and nonburned areas showed a significant increase (Table 13) for sheep IVDMD, but most of the samples for elk (Table 14) had large differences in digestibility from the first year to the second. The first year, the elk were stomach-pumped for their rumen fluid, while the second year they were sacrificed and the entire rumen contents were taken to the laboratory and strained. Perhaps I obtained more viable microbes in the rumen fluid of the elk that had been sacrificed than from those that were pumped. Results from the in vitro procedure itself, however, are generally recognized as a variable and subject to many confounding factors.

The changes in forage class composition and structure after a fire, though, may mean more to the ruminant than just the change in nutrient contents for the same species on burned areas versus nonburned areas. Brown et al. (1983) reported that fire in 1981 followed by an excellent growing season stimulated several-fold increases in herbaceous biomass production, especialy forbs. They found an 8- to 13-fold increase in forbs in 1982 and an almost 30-fold increase in forbs in 1983 on some burned plots in Manning Basin (Table 21). The increases in grass production on most of their plots were not as pronounced. The shrub component decreased as dramatically as the forb component increased, but the overall amount of biomass did not change much from year to year.

Table 21. Pre- and post-burn production data (pounds per acre) for burned plots in Manning Basin, 1981-1983.

Forage class	Pre-burn(1981)	1982	1982	1984
FORBS	72	551[1]	1111	810
GRASSES	288	461	450	440
SHRUBS	1222	231	321	560
OVERALL	1528	1243	1882	1810 approx

[1] 1982 data obtained from Dennis Simmerman, personal communication

The forbs that increased most on the plots were not ones analyzed in this study, but some forage quality information was collected for them the second year. The forb that was the most abundant on these sites was Iliamna rivularis, a mallow that was not found prior to burning (Brown et al. 1983). Fireweed (Epilobium augustifolia) was also common on the burned areas but was nonexistant on the control areas. Both of these forbs have high digestibilities, averaging 85% in July and 80% in August and September 1983. Crude protein levels were also high, averaging 20% for fireweed throughout the summer and 18% for the mallow. Where cattle and sheep grazed, these forbs seemed to be highly preferred and in many cases were grazed to ground level. This was especially true the first year after the burn when these plants were less stemmy. In this way, burning increased dramatically a highly preferred and nutritious forage that otherwise would not have occurred on the site. The benefits to ruminants, both wild and domestic, are substantial. These areas provide a more nutritious forage resource during the summer than if shrubs dominated the sites. These forages are also more accessible since obstructions from dense shrub motts that occur in aspen stands are reduced. The height of the forage is also totally within the grazing zone, whereas on nonburned sites dominated by shrubs, much of the biomass may be out of reach of animals. Thus, on burned areas, the animals would be able to obtain a high-quality diet with relative ease. This is very important because the condition of lactating females and rapidly growing young could be improved. Also, these animals may obtain better body fat stores in late summer and early fall to help them through the winter.

yet Kem Cannon found little in the way of nutr. differences. Foraging efficiency major benefit possibly.

One important aspect of this study is the apparently high nutritive quality of the understory in the aspen type, generally. Collins (1979) also found high nutrient levels in the aspen type. In my study, even though there were few effects due to burning for individual species, the overall forage quality for both the burned and nonburned plants was high. Very few species dropped below 50% digestibility even in late September. The shrubs averaged about 14% crude protein for all dates. The grasses and some of the forbs, however, went down to about 7% crude protein in late September. Even this low value is still within the maintenance requirements for adult mule deer (Dietz 1965). All of the plants were still green and growing in September, so ruminants would still be able to select a high-quality diet. Moreover, the samples analyzed for this study probably had a higher proportion of less nutritious stem to leaves than that of an animal's diet, which would result in lower forage quality for hand-plucked samples than the forage selected by the animals (Van Soest 1982). So, even though this study showed that burning does not lead to dramatic increases in forage quality for the same species, the aspen type is a very nutritious and valuable forage resource and should not, as a type, be allowed to succeed to conifers.

CONCLUSIONS

This study showed that prescribed burning did tend to increase forage quality of species occurring on both burned and adjacent nonburned sites, but only briefly. Crude protein levels were increased on burned sites the first year after burning for several shrub species. There was also some increase in digestibility and phosphorus and decreased Ca/P ratios the first year, but these did not exist past the middle of August, 1982, except in a few cases. The second year after burning, 1983, there were some decreases in forage quality. Pinegrass had lower digestibility and crude protein levels, possibly due to rapid maturation and extensive seed production on the burned areas. Most of the forages, however, had no significant differences in quality the second year.

Prescribed burning in the aspen ecosystem is beneficial to both wild and domestic ruminants. Burning resulted in a change in forage class dominance. Mallow and fireweed colonized the burns profusely and proved to be a very nutritious and palatable forage. These species were not present on the unburned sites. Burning also resulted in the reduction of obstructions due to dense motts of shrubs that typically occur under aspen stands. Ease of passage and accessibility to preferred forage for at least the first couple of years after burning was thus greatly improved for the ruminants. Height of available forage was also within the reach of all ruminants, even sheep.

Thus, while this study showed that burning did not consistantly improve forage quality of individual forage species, it did show that prescribed burning is a useful tool to improve habitat and forage availability. Burning also increased forage diversity and edge, which are especially important to wild ruminants.

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