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PREScribed FIRE AND CATTLE GRAZING INFLUENCES

ON THE VEGETATION AND ELK USE OF A

ROUGH FESCUE COMMUNITY

BY

Craig S. Jourdonnais

B.S. Wildlife Biology , University of Montana, 1982

Presented in partial fulfillment of the requirements
for the degree of

Master of Science in Forestry

UNIVERSITY OF MONTANA

1985

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FORESTRY

Prescribed Fire and Cattle Grazing Influences on the Vegetation and Elk Use of a Rough Fescue Community (100 pp.)

Director: Donald J. Bedunah

The emphasis of this research was to study the influences of fire and cattle grazing on specific vegetation characteristics and elk (Cervus elaphus) use parameters of a wolfy rough fescue (Festuca scabrella) grassland. Cattle grazing occurred during fall 1983. Burn treatments were backing fires and headfires during fall 1983 and spring 1984. Standing crop was measured from caged sites on all treatments during fall 1984. Elk use was measured from pellet group counts, counting numbers of plants grazed by elk, and clipping paired sites on all treatments during spring 1984 and 1985. Plant nutrient content analysis was conducted on rough fescue, Idaho fescue (F. idahoensis), and bluebunch wheatgrass (Agropyron spicatum) plants from all treatments. Total nonstructural carbohydrate (TNC) levels of rough fescue and Idaho fescue were also analyzed for all treatments. The effect of treatments on soil organic carbon content was determined.

Burn and cattle grazing treatments reduced rough fescue and total grass standing crop compared to controls. The spring headfire treatment produced greater standing crop of forbs compared to fall headfire and cattle grazing treatments. Total shrub standing crop was greatest on the cattle grazing treatment compared to other treatments. Burning and cattle grazing treatments were equally effective in reducing standing litter; whereas, fall burn and spring headfire treatments were most effective in reducing down litter accumulations. Burn and cattle grazing treatments increased elk use of rough fescue during winter 1985. Burn and cattle grazing treatments increased crude protein content of the 3 tested plant species compared to controls. Crude fiber content of the tested plant species varied considerably between collection dates. Differences in TNC levels of rough fescue and Idaho fescue were found between treatments. Peak TNC levels of both fescues was near the 20 July collection date. Wind erosion was more apparent on the fall burn treatments than other treatments. Burn treatments also had a trend of reduced organic carbon compared to grazed and control treatments.

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My parents deserve far more than words for their unsurpassed encouragement, support, and friendship. I love you both for showing me the great outdoors and suggesting that I spend my money on reels, rods, and guns instead of stereos. And to my beautiful wife, Marta, and our little toe-heads, Adam and Jenny; for without your love, understanding, and endless support, this paper would have meant nothing. And finally, thanks to God for creating the spectacular Sun River country, elk, and wolfy rough fescue.

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CHAPTER I

INTRODUCTION

Grasslands on the Sun River Game Range, Montana, represent a complex of native plant species, with rough fescue (Festuca scabrella Torr) being the most important and preferred as a forage plant for wintering elk (Cervus elaphus). Rough fescue is a cool-season perennial bunchgrass which, when healthy, produces an abundance of nutritious forage. The excellent forage value and palatability of this grass applies only to those plants that remain in a grazable condition. Grasses represent a major component of the winter diet for Sun River elk. However, elk avoid grazing grass plants which retain old-growth or 'litter'. Light or no grazing pressure, or an absence of fire, in rough fescue communities allows plant litter to accumulate, decreasing the community's attractiveness to wintering elk. Accumulation of plant litter affects specific rough fescue communities on the game range. Private landowners, whose property adjoins the game range, and officials of the Montana Department of Fish, Wildlife, and Parks are concerned over the existence of these 'wolfy' communities. A problem arises when elk move from the game range to graze on adjacent private lands. This research project was initiated from a desire by area game managers to

manipulate such a rough fescue community for the benefit of wintering elk and adjacent landowners.

My primary research objective was to develop techniques designed to remove excessive plant litter from a wolfy rough fescue community and increase forage availability and quality for elk wintering on the game range. Specifically, I compared the influence of seasonal burning and fall cattle grazing on: 1) production and composition of a rough fescue community; 2) elk use; 3) nutrient content of rough fescue, Idaho fescue (F. idahoensis) and bluebunch wheatgrass (Agropyron spicatum); 4) total nonstructural carbohydrate reserves of rough fescue and Idaho fescue; and 5) soil organic carbon content.

CHAPTER II

LITERATURE REVIEW

Sun River Game Range History

Rough fescue grasslands evolved with grazing by big game and frequent fires. Pictorial records and memoirs from travellers during the 1700-1800's document fire's occurrence within rough fescue grasslands. Wright and Bailey (1982) quoted an Alberta traveller in 1793 describing the extensive rough fescue communities as "...being constantly on fire in one place or another". Burning was a culturally accepted practice of the Plains Indian. Their use of fire in manipulation of vegetation and wildlife distribution, whether planned or unintentional, created diversity among plant communities that benefitted several species of big game (McCabe 1982). Quoting news articles from the Great Falls Tribune, Picton and Picton (1975) indicated that wildfires burned roughly 10% of the Sun River country annually. Fire suppression activities on the game range during the spring-fall seasons of 1981-1984 resulted in the suppression of 15 fires, 14 of which were natural ignitions. Wright and Bailey (1982) and Arno (1980) estimated a fire frequency of 5 to 10 years for grassland environments with level to rolling topography or in association with forested areas of the Northern Rockies. Historical records indicate

that grazing activity also exerted frequent influence on these rough fescue foothills.

Expeditions during the 1800's noted an abundance of wild ungulates along the East Front of the Rocky Mountains. The Stevens exploration party reported vast numbers of pronghorn antelope (Antilocapra americana), bighorn sheep (Ovis canadensis), elk, and "an almost inconceivable number of buffalo" (Bison bison) (Picton and Picton 1975). As the great herds of big game diminished during the late 1800's, cattle filled the void. Historically, the majority of the Sun River elk herd migrated to the East Front foothills as snow accumulated on summer ranges. During the late 1800's severe forage competition from domestic livestock and the effects of market hunting forced a dwindling elk herd to winter west of the Continental Divide (Picton and Picton 1975). Despite overgrazed ranges, Sun River elk began to reappear on the foothill winter ranges in 1925. Private landowners met this reappearance with widespread disapproval. The Montana Fish and Game Department responded to ranchers complaints by hiring local riders to harrass elk from private lands back onto the mountainous areas administered by the U.S. Forest Service. Rathbone, who's land received persistant use by migrating elk during winter and spring, felt the Department conducted an ineffective harrassment program. Rathbone's protests included an advertisement in a Chicago newspaper requesting experienced

machinegunners to help alleviate his elk troubles. The gunners failed to appear. Rathbone terminated his protests by illegally shooting an elk on his property. This incident evolved into the landmark case 'The State of Montana vs Rathbone'. The Supreme Court ruled in favor of Rathbone. The court also presented restrictive provisions that defined conditions for use of reasonable force in protecting private property from game damage.

In 1947, two ranchers in the Sun River area offered their property to the Department for purchase as a game range. The Department acquired these properties and later added several smaller tracts, which collectively form the 8100ha Sun River Game Range. Establishment of the game range was a major step toward reducing elk damage to private lands. The Department believed that fire and domestic livestock grazing presented undesirable forage competition to wintering elk, and eliminated both upon acquiring the game range. Game managers also realized the need for security and improved range conditions on the game range to attract elk from adjoining ranches. This absence of fire and grazing pressure allowed specific rough fescue communities to accumulate undesirable amounts of plant litter. Harvey (1980) expressed two management concerns upon analyzing a wolfy rough fescue community on the game range. He recorded 78 plant species within the rough fescue-Idaho fescue/rough fescue-bluebunch wheatgrass

habitat type complex and he suggested that excessive plant litter hampered this community from maintaining a higher plant species diversity. Secondly, litter production affected a large area with excellent potential for producing quality elk forage. Knight (1970) observed that Sun River elk preferred fescue plants free from old-growth material. Only 5% of elk spring grazing on rough fescue and 2% on Idaho fescue were plants left ungrazed the previous winter. Bailey and McLean (1980) observed that mule deer (Hemionus odocoileus) carefully avoided vegetation with heavy accumulations of litter. Dead stems and leaves of bluebunch wheatgrass affected the grazing behavior of mule deer by imposing a barrier to new growth.

The amount of use of rough fescue by elk in wolfy rough fescue areas is not representative of how elk use the remainder of rough fescue on the game range. Forage use transects located throughout the game range indicate that 70 to 90 % of the rough fescue plants receive some degree of elk use during the winter and spring months.

PLANT LITTER

Apparently, the presence of litter encourages healthy soil development and soil-water relationships. However, the influence of litter buildup on herbage production varies between grassland associations. Because this research was designed to manipulate plant litter, I present views from

various research papers dealing with plant litter dynamics.

Dyksterhius and Schmutz (1947) suggested that litter accumulations on grasslands should be an important component in range condition and trend determinations. Generally, plant litter accumulations on rangelands correlates directly with herbage production; however, an excess of litter may impede herbage growth (Heady 1975). The plant litter-range condition relationship is strongly tied to litter's influence on edaphic parameters.

Plant litter absorbs and retains moisture, and reduces soil surface drying (Pearse 1946). The rate of water intake on a rough fescue grassland in the Alberta foothills was directly related to condition of ranges and amount of plant litter present. Infiltration increased with increasing amounts of litter and standing vegetation (Johnston 1961). Hopkins (1954) found infiltration much higher where healthy mulches existed on a Kansas mixed-grass prairie. He stated that, under lab conditions, 7.6 cm of mulch decreased evaporation 67% compared to bare mineral soil during a one week test period. At the end of the growing season a mulched plot retained available soil water to a depth of nearly 1.2 m, whereas an unmulched plot retained available soil water to a depth of 0.6 m. Fifteen years without grazing or fire on a Nebraska prairie resulted in a deep mulch layer which enhanced infiltration and reduced evaporation (Weaver and Rowland 1952). However, a thick

cover of litter may intercept rainfall and cause significant loss of water to soil. Saturated litter held 0.8 cm of water above the soil with most being lost to evaporation. There appears to be a level where litter accumulations create unfavorable conditions for plant growth. Identifying these undesirable conditions are important to the plant community's health and productivity.

Lower soil temperatures beneath litter of an undisturbed grassland delayed spring growth 3 weeks and herbage yields were reduced 26 to 57% compared to grazed prairie (Hopkins 1954). Basal area of grasses declined in tallgrass communities as litter accumulated (West 1965). Mulch buildup in an unburned, undisturbed grassland increased Kentucky bluegrass (Poa pratensis) and tree species and eventually decreased grass production (Towne and Owensby 1984). Litter accumulations in an undisturbed Nebraska prairie eventually depressed herbage yields and reduced the number of plant species (Weaver and Rowland 1952). Sauer (1978) concluded that removal of standing litter from bluebunch wheatgrass plants decreased the weight of newly emerging leaves and culms by 28%. Influences of grazing animals often control or reduce litter accumulations on rangelands.

Plant litter largely disappeared under very heavy, long-term grazing on a rough fescue grassland in the Alberta foothills (Johnston et al. 1971). A pasture receiving light grazing on a season-long basis retained 9175 kg/ha of litter, whereas, a pasture receiving very heavy cattle grazing retained 3891 kg/ha of litter. However, 10 years of very heavy season-long grazing failed to cause a significant increase in soil erosion. Light grazing on a mixed grass prairie tended to increase amounts of down litter and decrease standing litter; whereas, moderate grazing decreased down and standing litter (Dix 1960). Hopkins (1954) found that litter from an ungrazed shortgrass prairie measured 5362 kg/ha compared to 1885 kg/ha from a heavily grazed shortgrass prairie. Dix (1960) found that litter accumulations which exceeded 1234 kg/ha failed to reduce forage production of a *Stipa* or *Agropyron* community in North Dakota.

When large amounts of litter cause stagnation of the tallgrass and southern mixed-grass prairies, fire is an effective tool for increasing plant growth (Weaver and Rowland 1952, Sharrow and Wright 1977). Mulch structure of burned areas recovered to unburned levels in four growing seasons on a North Dakota prairie. However, grazing slows litter recovery (Dix 1960). Once on the ground, litter requires about three years to decompose (Old 1969). The rate of organic decomposition appears related to litter

compaction, depth, and evaporation potential (Dix 1960). After three years, fresh mulch begins to accumulate on the soil surface (Old 1969). Antos et al. (1983) stated that the burned surface of a foothill rough fescue grassland absorbed more solar radiation. The lack of litter allowed better heat penetration, resulting in greater daylight heating. Absence of litter probably facilitated radiational cooling at night.

Removal of litter by fire, grazing, or other methods causes a dramatic change in food supplies, water content, temperature, and pH of soil, which causes a threefold reduction in numbers of soil fauna as well as a loss of many genera. Loose organic material serves as a refuge for soil organisms when water temporarily replaces air pores in soil (Pearse 1946). Following fire, the rate of organic decomposition appears to be remarkably reduced for several years. As litter increases, water loss from organic materials is reduced and conditions are more favorable for microbial decomposition (Dix 1960).

Fire Temperature

Vegetation response to fire is partially dependent upon the method and season of burning. Fire behavior characteristics of head and backing fires often vary dramatically. Monitoring this variation in fire types may provide additional information for explaining specific

changes in vegetation production and composition; and further our knowledge and abilities in establishing fire prescriptions.

Bailey and Anderson (1978) suggested that the primary factors influencing fire temperatures included kind, quantity, and spatial distribution of fuels, weather conditions prior to and during burning, microrelief, and type of fire. They found that head fires burned 95% of a given area compared to 69% for backing fires. Anderson (1972) reported that the maximum head fire temperatures ($146-271^{\circ}\text{C}$) in a *Festuca-Stipa* grassland were greater at all heights measured than the maximum temperature (143°C) in the backing fire. The variability of maximum temperatures in head fires was considerably greater than the variability measured in the backing fires. Fahnstock and Hare (1964) report similar findings for fire occurring in longleaf pine (*Pinus palustris*) vegetation. Bailey and Anderson (1978) found that head fires were consistently hotter than backing fires at all heights measured in grass and shrublands. Above 46 cm, head fires were $80 - 200^{\circ}\text{C}$ hotter than backing fires (Fahnstock and Hare 1964, Bailey and Anderson 1978). Lindemuth and Byram (1948) found maximum temperatures in backing fires were higher than maximum head fire temperatures in longleaf pine vegetation. Beaufait (1965) burned a ponderosa pine (*Pinus ponderosa*) needle bed under laboratory conditions and observed that backing fires

burned longer, deeper, and slower than head fires. He also stated that wind speed had no detectable influence on the rate of spread of backing fires. Daubenmire (1968) suggested that backing fires in grasslands were hotter and produced their maximum temperatures nearer the ground, in comparison to head fires.

Wright (1974) concluded that mineral surface temperatures of grassland fires vary from 83 - 682°C for fuels that range from 1731 to 7868 kg/ha. Temperatures above 71°C in these fires generally last from 1 to 2 minutes, depending on the moisture content of the plant. Bunchgrasses with large accumulations of dead plant material often generate high temperatures for a long period of time after the main fire has passed (Wright 1971). Fuels within these plants generate temperatures up to 537°C within 1 hour. Temperatures above 93°C for more than two hours are common in large bunchgrasses. This is why small bunchgrasses or rhizomatous grasses recover quickly after a fire compared to large decadent bunchgrasses. Daubenmire (1968) stated that, where deliberate burning is desirable to eliminate litter, selection of a date when the soil is moist and the litter has barely dried minimizes the rate of heat release and reduces risk of damaging plants. Britton et al. (1983) explained that for Great Basin soils dominated by Idaho fescue, high soil moisture levels are unnecessary and undesirable. An increase in soil moisture raises the

thermal conductivity potential; thereby creating a more direct and efficient path for heat impulses to reach meristematic tissue of grasses.

Fire Effects on Vegetation

Fire in semi-arid grasslands may have a detrimental effect on plant productivity. These detrimental effects include the influence of burning on snow hydrology, soil water, and ultimately plant water stress (Redmann 1978). Wildfires reduced forage production, plant vigor, basal area, and number of flowering culms in a *Festuca*-*Danthonia* community in the foothills of southwestern Alberta (Wright and Bailey 1982). A prescribed burn, prior to growth initiation (mid-April) of foothill rough fescue, maintained forage production and reduced basal area the first year when the growing season precipitation was normal (Klumph, pers. comm., Wright and Bailey 1982). The second year when growing season precipitation was below normal, forage production was significantly greater on burned areas than on unburned areas. Antos et al. (1983) reported that a June wildfire in western Montana on an ungrazed foothill rough fescue grassland reduced the canopy cover of grasses due primarily to the decrease of rough and Idaho fescue. Three years following the fire, Idaho fescue had completely recovered. Rough fescue had increased but remained below unburned levels. Large diameter rough fescue plants

experienced greater damage than smaller plants; suggesting that prolonged fire-free intervals may be detrimental to rough fescue once fire returns. Forb canopy cover increased 139% the first growing season following the burn. A July wildfire in the same area decreased cover and frequency of Idaho fescue and bluebunch wheatgrass; however, cover and frequency of rough fescue was maintained (Mitchell 1958). Mitchell (1958) observed a 4 to 5 inch stubble remaining on burned rough fescue plants, perhaps indicating a moderate fire severity. Anderson (1972) found canopy cover of plains rough fescue (F. hallii) decreased 6% following a fall burn and 26% following a spring burn. However, burning had little effect on total herbage production when compared to unburned areas. Anderson and Bailey (1980) found annual spring burning of a plains rough fescue-western porcupine grass (Stipa spartea) community reduced foliar cover yet increased frequency of plains rough fescue. Burned plains rough fescue plants maintained a greater tiller density than unburned plants for the first two growing seasons following the fire (Sinton 1980). Plains rough fescue and silverberry (Elaeagnus communtata) were most reduced by spring burning; western porcupine grass, a warm season species, was most affected by fall burns (Bailey and Anderson 1978).

Conrad and Poulton (1966) found that a hot July wildfire in northeastern Oregon killed many more Idaho fescue plants than bluebunch wheatgrass plants. Nimir and Payne (1978) reported that Idaho fescue was significantly damaged by a spring burn in southwestern Montana. Uresk et al. (1976) stated that an August wildfire in south-central Washington increased bluebunch wheatgrass 24% over unburned areas during the first growing season following the fire. Apparently, Idaho fescue's growth form is more susceptible to continuous burning after the passage of the flaming front than is rough fescue or bluebunch wheatgrass (Wright and Britton 1976). Wright (1971) found that a bunchgrass with a high density of fine fuels maintained heat longer within the clump than did one with coarse culms and a lower density of fine fuels.

Grazing Effects on Vegetation

Grazing influences on rough fescue grasslands differs from fire's effects in season, intensity, and frequency of defoliation. Basal area of rough fescue in the foothills of Alberta decreased from 7.2% after light grazing to zero after very heavy grazing. The pastures under study received season-long grazing for 10 years (Johnston 1961). Percent basal area of vegetation on ungrazed or lightly grazed pastures changed from dominance by Parry's oatgrass

(Danthonia parryii) to dominance by foothill rough fescue within eighteen years. Under very heavy grazing (0.2 ha/AUM) Idaho fescue, other grasses, forbs, and shrubs had greater percentages of basal area compared to ungrazed or lightly grazed (0.8 ha/AUM) pastures (Johnston et al. 1971). McLean and Wikeem (1985b) concluded that weekly clipping of foothill rough fescue to a height of 5 cm from mid-May to late June resulted in a mortality of 71%. When fall clipping was added to this treatment the mortality of rough fescue plants increased to 92%. Season-long defoliation to a height of 20 cm or clipping to 5 cm only in the fall caused no apparent mortality. The high mortality of fescue to clipping treatments that began near the end of the rapid growth phase and continued past the end of leaf growth was related to the lack of photosynthetic tissue present after the clipping treatment terminated. When clipping treatments ceased before the end of leaf growth or when photosynthetic material was retained, injury due to clipping was reduced. The decrease of foothill rough fescue in heavily grazed pastures cannot be explained on the basis of heavy seed production or shoot apices being elevated and becoming accessible to grazing animals. The decrease in rough fescue was a result of the erect growth habit and the ease with which close grazing can remove most of the photosynthetic tissue (Johnston and MacDonald 1967).

Bailey et al. (1980) were unable to illustrate significant long-term changes from a six year grazing study on a central Alberta plains rough fescue- western porcupine grass rangeland. However, heavy grazing (75% utilization) in either fall or June decreased grass production. Light grazing results were similar to results for control pastures.

Mueggler (1975) concluded that Idaho fescue recovery from severe clipping treatments might be expected in six to seven years. Bluebunch wheatgrass plants of low vigor may take eight years to completely recover from similar clipping intensities. Bluebunch wheatgrass appears to be more sensitive to heavy use than Idaho fescue. Pond (1960) considered leaf length an effective indicator of plant vigor in Idaho fescue. Fall or summer grazing resulting in near total herbage removal affected plant vigor minimally. However, total herbage removal by clipping in late spring caused significant mortality and vigor reduction in surviving plants (Daubenmire 1940). McLean and Wikeem (1985a) found that bluebunch wheatgrass plants that were subjected to weekly clipping to heights of 5 cm during the growing season or late spring were unable to regrow prior to summer drought. These plants experienced severe mortality. Plant mortality after fall clipping was similar to control plant mortality. Canopy coverage of bluebunch wheatgrass, foothills rough fescue, and kentucky bluegrass was five-fold

greater in 30 year old exclosures compared with depleted range outside the exclosures. Sampling at the time of exclosure construction (1931) found that the site was dominated by Sandberg bluegrass (Poa sandbergii), low pussytoes (Antennaria dimorpha), and dwarf fleabane (Erigeron compositus). Average herbage production during the period 1959 to 1966 was 98% greater (1025 kg/ha) inside the exclosures than outside (519 kg/ha). The Lordbun and Hamilton exclosures in British Columbia progressed from poor to excellent condition in 40 years. Bluebunch wheatgrass recovered within 10 years, whereas rough fescue made its greatest advances in the following decade within the East Mara exclosure (McLean and Tisdale 1972). Mueggler and Stewart (1981) rated 13 grassland habitat types in Montana for productivity of herbage and livestock forage. The foothill rough fescue-Idaho fescue habitat type rated third (1562 kg/ha) for total standing crop and second (1260 kg/ha) for forage species standing crop. The foothills rough fescue-bluebunch wheatgrass habitat type rated eighth (1082 kg/ha) in total standing crop and seventh (860 kg/ha) in forage species standing crop. Yearly variations in total standing crop measurements were 745 kg/ha on the foothills rough fescue-Idaho fescue habitat type and 610 kg/ha on the foothills rough fescue-bluebunch wheatgrass habitat type. Amount of soil water available for plant growth was the primary factor influencing variability in standing crop

within habitat types.

Plant Nutrient Content

The importance of forage plant nutrient content may be approached from two avenues, one being animal nutrition and the other being how increases in plant nutrient levels influence animal distribution. Chemical composition of forage plants varies with season, change in stem/leaf ratio, the normal maturing processes, and translocation of nutrients within plants (Anderson and Scherzinger 1975). Johnston et al. (1968) reported that protein content of rough fescue on unfertilized Alberta foothill rangeland was 11.1% at leaf stage, 5.2 % at seed-ripe, and 3.0% when cured. Daubenmire (1968) suggested that most published research regarding range burning indicates nutrient content of grasses increases after a fire, making them more attractive to grazing animals. Stark (1980) concluded that fire temperatures of 280 - 320°C were required to induce significant increases in nutrient content of sprouting forage shrubs following fire in western Montana forests. Grelen and Epps (1967) found no difference in crude protein levels between southern bluestem ranges that were burned or mowed. Peek et al. (1979) observed unburned areas of an Idaho bighorn sheep (Ovis canadensis)-mule deer (Odocoileus hemionus) winter range where plant litter accumulated that was not removed by grazing. Adjacent fall burned areas were

utilized heavily enough to prevent accumulations of dead plant material. Utilization was consistently greater on burned areas during a four year period. Stoddart et al.(1975) explained that grazing animals usually return to previously grazed plants. This repeated grazing or spot overgrazing results in unused or wolf plants. Fire is often implemented to remove accumulated litter so that new growth may be readily available to grazing animals.

Research on the use of livestock to manipulate wildlife forage has received little attention. However, Anderson and Scherzinger (1975) suggest livestock grazing may prevent wolf plant conditions or influence plant phenology to improve nutritive value of plants at maturity.

Aside from water, protein is considered to be the most important nutrient for animals. Elk require about 5.5% dietary crude protein for maintenance during winter months (Nelson and Legee 1982). Actual composition of amino acids is of little consequence to ruminants. Rumen bacteria restructure amino acids to satisfy their own protein requirements. Crude protein, which includes nonprotein sources of nitrogen, is generally used to describe the quality of a forage species. The rumen microorganisms use the nitrogen from these materials for synthesis of microbial protein (Lloyd et al. 1978). When grasses initiate new spring growth, crude protein levels are at a peak and fiber content is at its lowest levels. However, newly emerging

grasses contain so much water that grazing animals have difficulty obtaining the required amounts of dry matter (Heady 1975). Grasses decline in digestible protein rapidly after initial growth, and at anthesis, generally fail to meet the lactation requirements of ruminants. This is related to the rapid loss of total protein and a more rapid decrease in protein digestibility which follows advanced growth. Mature grasses are poor sources of digestible protein. However, native grasses are generally considered good to excellent sources of energy due to their high cellulose content (Cook 1972). During winter, grasses lack adequate amounts of protein yet remain excellent sources of energy for ruminants. During winter feeding trials in Montana, Geis (1954) found that elk preferred herbaceous material to woody forage. However, daily weight loss was reduced by one half when elk consumed herbaceous and woody forage in a ratio of 2:1 compared to diets of hay or bunchgrasses alone. A trade-off exists in winter elk diets where grasses offer greater digestibility and energy sources yet lack the protein content found in less digestible browse.

As fiber increases in the diet, digestion rates slow. Rumen fermentation of plant structural carbohydrates produces volatile fatty acids that provide essential energy to the elk (Lloyd et al. 1978). Crude fiber components include cellulose, hemicellulose, and lignin. Lignin is not

a carbohydrate; however, the amount of lignin present effects digestibility. For most forages cellulose is the major component of crude fiber, therefore, the digestibility of crude fiber depends largely on the digestibility of cellulose (Lloyd et al. 1978). Diets deficient in nitrogen may curtail the reproduction and growth of rumen bacteria that digest cellulose, thereby slowing cellulose digestion.

Nonstructural Carbohydrate Reserves in Grasses

Season, intensity, and frequency of defoliation are important influences on plant carbohydrate levels. Burning and grazing inflict different influences on carbohydrate reserves of plants. Carbohydrate reserves are used by plants as substrate for growth and respiration (White 1973). The principle reserve substances in grasses are certain types of carbohydrates, namely sugars, fructosans, glucosans, and starch. The more complex polysacharides, such as cellulose and hemicellulose, are plant structural materials and unavailable for use as reserves (Weinmann 1952). Perennial plants native to temperate latitudes appear to accumulate fructosans and sucrose in stem bases and rhizomes. Reserves may be used when conditions are favorable for growth or regrowth. Demands may accompany partial or entire defoliation of plants by fire or grazing animals (Trillica 1977).

In the majority of grasses, minimum reserve levels occur during early vegetative growth, but lows may also occur during flowering and fall greenup (Cook 1966). McLean and Wikeem (1985b) hypothesized that fall carbohydrate accumulations from photosynthesizing tissue in foothill rough fescue was critical to the survival of plants which experienced late spring defoliations. Bluebunch wheatgrass was more sensitive to season-long or early spring defoliation. Daer and Willard (1981) reported that bluebunch wheatgrass carbohydrate reserves reached a minimum during early spring.

Carbohydrate movement occurs toward the centers of active growth and storage in grasses. With morphological changes, new centers of carbohydrate utilization and storage are formed. Carbohydrate movement in grasses generally occurs from the leaf blade through the sheath and into the node where carbohydrates enter the vascular system of the stem or culm (Moser 1977). The ability of a grass to synthesize and store carbohydrates is a major factor in the survival of that grass to remain a viable component within a community.

Soil Organic Matter

Organic matter serves as a granulating agent in soils. A high correlation exists between organic matter and aggregation of soils containing less than 25% clay (Baver 1972). Organic material alone has very little effect on soil structure. Brady (1974) stated that soil organic matter increases soil water-holding capacity and supply and availability of nutrients. Mineral surface soils contain a trace to 20% organic matter. Well drained prairie soils in Minnesota range from 3.4 to 7.4% organic matter. The transitory products of microbial synthesis are responsible for aggregate stability (Baver 1972). Baver (1972) also stated that Chernozem soils possess a high state of aggregation, as a high percentage of the small particles are aggregated. Size distribution, quantity, and stability of the aggregates are important in determining both the amount and distribution of the pore spaces associated with the aggregates and the susceptibility of the aggregates to water and wind erosion.

Organic matter of a rough fescue grassland in the Alberta foothills under light grazing was 11.71% and under very heavy grazing was 9.68%. Very heavy grazing reduced soil organic matter and changed the color of the Ah horizon from black to dark brown (Johnston et al. 1971). Sharrow and Wright (1977) stated that humus content in soils of grasslands will recover in one or two

years after a burn in the 100 cm precipitation zone. Humus recovery may take five to eight years in the 50 cm precipitation zone. Whigham (1976) found that increased soil temperatures following spring fires can greatly enhance breakdown of soil organic matter.

CHAPTER III

STUDY AREA DESCRIPTION

Location

Field research was conducted on the 8100 ha Sun River Game Range, located 112 km west of Great Falls, Montana. The study area is known locally as Fescue Flats and is located in sections 35 and 36 of township 21 N and range 8 W on the Barr Creek quadrangle.

Vegetation

The study area is located in a transition zone where the Great Plains meets the East Front foothills of the Rocky Mountains. Topography on Fescue Flats is bench-like, sloping slightly to the southeast with gently rolling knolls and kettles. Located at 1250 m in elevation, the study area encompasses approximately 150 ha. Harvey (1980) described vegetation on the study area as a rough fescue-Idaho fescue / rough fescue-bluebunch wheatgrass habitat type complex, with rough fescue clearly the dominant vegetation. Major grass species are rough fescue, Idaho fescue, bluebunch wheatgrass, prairie junegrass (Koeleria cristata), Sandberg bluegrass (Poa sandbergii), and plains muhlenbergia (Muhlenbergia cuspidata). Dominant forb species include

blazing star (Liatrus punctata), lupine (Lupinus sericeus), white prairie aster (Aster falcatus), and bastard toadflax (Comandra umbellata). Shrub species include common snowberry (Symphoricarpos albus), Arkansas rose (Rosa arkansana), shrubby cinquefoil (Potentilla fruticosa), skunkbush (Rhus trilobata), horizontal juniper (Juniperous horizontalis), silverberry (Elaeagnus comunata), and fringed sage (Artemesia frigida). A complete species list is found in Appendix 1.

Soils

The soils of Fescue Flats are a Judith-Windham stoney loam characteristic of glaciated uplands (U.S. Department of Agriculture 1980). The soil of Fescue Flats is an excellent mollisol and the well-defined, old soil profile suggests that a series of ridges to the west protected this area from glacial action (Harvey per comm. 1984).

Climate

Continental and marine flows influence weather along Montana's East slopes of the Rockies. However, continental flow in conjunction with the Alberta Storm Belt dominate the game ranges' weather patterns. Mean annual temperature is

6.4°C. Mean temperature for January reaches -5.2°C and 16.9°C for July (Harvey 1980). The game range also experiences frequent warm chinook winds during the winter months along with seasonally windy periods. Winds in excess of 96 km occur during the early winter months. Annual precipitation averages 38 to 45.7 cm on the foothills. Approximately one-third of the annual precipitation occurs during April, May, and June (Harvey 1980). Annual precipitation for 1983 was 37.9 cm; 9.4 cm below the 60 year norm (U.S. Weather Bureau 1983). Precipitation amounts for 1984 totaled 40 cm; 6.6 cm below the 60 year norm (U.S. Weather Bureau 1984).

CHAPTER IV

METHODS AND MATERIALS

Cattle Grazing

The cattle grazing treatment was 104 cow/calf pairs on a 104 ha pasture from 18 October, 1983 to 22 December, 1983. The cattle pasture was separated from burn and control plots by an electric fence. Forage use by cattle was measured by an actual weight difference method (Klingman et al. 1943). Initially, 6 lm^2 agronomy cages were located on the grazing pasture on areas that supported representative rough fescue plants. However, after the termination of the cattle grazing, only four cages remained in a useable condition.

Prescribed Fire

Head and backing fires during 17 October, 1983 and 15 April, 1984 represented burn treatments. The 2 ha plots were replicated three times in a completely randomized design (Appendix B). Firelines were constructed by mowing 3 m wide strips around each plot and burning these strips using a modified version of the double wet line technique designed by Martin et al. (1977). A road grader was used to scrape two parallel 0.3 m wide firelines around various burn plots to expedite fireline construction. Once ambient conditions met the burning prescription, burn plots were

ignited using a drip torch containing a 3:1 diesel-gas mixture. Plots receiving head fire treatments were ignited on the windward perimeter of the plot; whereas plots receiving backing fires were ignited on the leeward plot perimeters. Fire weather data were collected each 0.5 hr during the burning period with a belt weather kit. Flame length, rate of spread, and related data on fire behavior were also recorded. Fire behavior data for headfires was estimated using a TI-59 calculator modified for fire behavior predictions (Burgan 1979). Temperatures of fall burns were recorded using Detectotemp paints applied to glass strips (15 cm x 2.5 cm x 0.3 cm). Five rows of five glass strips were randomly placed on each burn plot.

Vegetation Measurements

Standing Crop

Botanical standing crop was measured by clipping 1 m² caged sample sites on each treatment plot. Each treatment plot had four caged sample sites located on an area that was representative of the plant community on the treatment plot. Twelve caged sample sites were located in the grazing pasture using similar criteria. Vegetation obtained from clipping was separated by species or plant group that included rough fescue, Idaho fescue, bluebunch

wheatgrass, miscellaneous grasses, Carex species, forbs, shrubs, down litter, and standing litter. Clipping results are expressed in kg/ha of oven-dried weight (60°C). Two caged sample sites were clipped in each treatment site during June 1984. The remaining caged sample sites on each treatment plot were clipped during October 1984. Six caged sample sites were clipped on the grazing treatment during each of the two clipping dates previously mentioned. All cages were relocated upon completion of the 1984 clipping activities.

Composition

Plant composition was determined from the standing crop measurements. Plants clipped from each caged sample site were categorized as previously described and results were expressed as percent composition based on oven-dried weight. Composition data for grasses, sedges, forbs and shrubs was taken from standing crop clipping dates. Permanent photo points were established on each treatment plot.

Elk Use

Forage use by elk was estimated using the paired plot weight estimate (Klingman et al. 1943). Measurements involved the clipping of two caged and uncaged sample sites on each treatment plot, six on the grazing pasture, during

spring 1984 and 1985. The difference in weight among the vegetation categories described in the standing crop methods between caged and uncaged sample sites was expressed as percent elk utilization based on oven-dried weight. Cured 1984 plant material was analyzed separately.

Two 2 x 90 m pellet group transects were located in each treatment plot with six on the grazing pasture. Current year pellet groups were counted to estimate elk-use-days (Neff 1968). Pellet groups were counted during the spring of 1984 and 1985.

Pellet group transects were also used to count percent rough fescue and Idaho fescue plants that received grazing by elk during winter and spring. A total of 50 rough fescue plants and 25 Idaho fescue plants were counted on each transect using the pace transect method (Costello and Schwan 1946). Measurements were gathered during the spring of 1984 and 1985. Visual observations of elk using the study area by the game range manager and research personnel supplemented elk use field data.

PLANT NUTRIENT AND CARBOHYDRATE ANALYSES

Crude protein (%) and crude fiber (%) were determined in the foliage of rough fescue, Idaho fescue and bluebunch wheatgrass for each treatment. Total nonstructural carbohydrate (TNC) reserves, expressed in mg/g, were determined for basal root crowns of rough fescue and Idaho fescue. Five samples of each plant species were collected at two week intervals beginning on 21 April, 1984. When the plants reached the flowering stage, 15 June, collections were made once each month until 7 October, 1984. Plants on spring burn treatments were collected for TNC analysis throughout the collection period. However, burning temporarily setback leaf growth and collections for plant nutrition analysis were delayed accordingly. Collected samples were immediately placed in a cooler containing dry ice or ice. Samples were transported in the cooler to a drying oven where they were oven-dried at 105°C for 5 minutes to halt enzymatic activity and then allowed to dry for 24 hr at 60°C All oven-dried foliage samples were then ground through a Wiley Mill fitted with a 40 mesh screen. Basal root crown samples were ground through a 60 mesh screen.

An oven-dried 0.1 g portion of each foliage sample was used for crude protein analysis. Samples were digested using a Tecator Digestion System. Upon completion of digestion, total nitrogen was determined using a Tecator Kjeltac System I distilling unit. Total nitrogen values were multiplied by 6.25 to obtain crude protein values based on oven-dry weight (Lloyd et al. 1978).

An oven-dried 1.0 g portion of each foliage sample was used for crude fiber analysis. Percent cell wall-cell constituents (neutral detergent fiber) was determined following the methods of Goering and Van Soest (1970).

Crude protein and crude fiber analyses were used to estimate the tested plant species palatability, digestibility, and overall forage quality. Both nutrient components were used to indicate possible influences of treatments on forage nutrient content.

Samples for TNC determination were washed with tap water before grinding. A 0.1 g portion of each sample was analyzed for TNC reserves by an enzyme digestion technique (da Silveira et al. 1978) and an acid hydrolysis method (Krueger 1985) to measure fructosans which were undetected by the enzyme method. The TNC data were used to indicate how treatments influenced reserves of these two plants. During plant collections, soil water samples and temperature were taken from the 0-18 cm soil depth range. The phenological stage, leaf length, and basal diameter of each

plant collected were also recorded. Soil water samples were removed from the soil profile with the aid of a soil core, weighed, oven-dried at 60°C for 24 hr, and re-weighed to obtain % soil water on a gravimetric basis.

SOIL ANALYSIS

The upper 1 cm of mineral soil was removed from two representative locations within a fall burn, spring burn, cattle pasture, and control treatment site. Samples, collected on 5 May, 1984, were transported to the University of Montana range lab and air-dried for one week at 22°C. Duplicate 0.1 g samples were analyzed for organic carbon following the method outlined by Walkley and Black (1934). Results from this analysis were used to indicate treatment influences on soil erosion and long-term vegetation production. The remainder of the soil samples were taken to the U.S. Forest Service Materials Testing Laboratory in Missoula, Montana. Samples were then analyzed using a dry-sieve technique (Cole 1939). Results were used to indicate treatment influences on erosion of soil particles.

STATISTICAL ANALYSIS

Data from standing crop and elk use measurements were analyzed using a single classification analysis of variance (Sokal and Rohlf 1981) to compare standing crop of each vegetation category by treatment. A Duncan's new multiple range test (Steel and Torrie 1960) was used to test all possible comparisons between means. A 0.10 alpha level was used.

Data from plant nutrient and TNC analysis were analyzed using a two-factor analysis of variance (Sokal and Rohlf 1981) to compare crude fiber, crude protein, and TNC for each tested species by treatment and date. A new Duncan's multiple range test (Steel and Torrie 1960) was used to test all possible comparisons between means. A 0.05 alpha level was used.

CHAPTER V

RESULTS AND DISCUSSION

Vegetation Use By Cattle

Cattle grazing during Fall 1983 removed 42% of the current year above ground material of rough fescue, 48% of Idaho fescue, and 91% of bluebunch wheatgrass. Cattle use information on Idaho fescue and bluebunch wheatgrass is based on fewer samples than rough fescue. Paired plots were established with rough fescue as the target species. Therefore, rough fescue was always present on caged and uncaged sample sites. Associated grasses may have been absent from one or more of the sample sites. I feel that this caused lower use value for Idaho fescue and a higher value for bluebunch wheatgrass than was observed in the field.

Mesic swales, supporting timothy (Phleum pratensis) and Kentucky bluegrass (Poa pratense), were heavily used by cattle. Standing litter was effectively eliminated from these swales as cattle grazed available forage to within 2.5 cm of the soil surface. Cattle also appeared to select for threadleaf sedge (Carex filifolia) and moist cured arrowleaf balsamroot (Balsamorhiza saggitata) leaves. Cattle tended to graze the rough fescue dominated sites with regularity only after grasses on the swale areas were used entirely.

Grazing of rough fescue clumps was inconsistent and spotty. Initially, cattle selected for plants that retained little or no down litter. Cattle usually removed all standing litter from such plants. The majority of rough fescue plants had enough down litter within the clumps to discourage close grazing. Frequently, cattle removed the standing litter which protruded through the dense clump of down litter, leaving the remainder of the plant ungrazed. Down litter on most individual rough fescue plants accumulates on the downwind portion of the stem bases in response to frequent winds and seasonally blowing snow. Standing litter on the upwind portion of these plants is unincumbered by down litter and received close grazing by livestock.

Rough fescue plants appeared to suffer damage from stem base removal and trampling by cattle. Evidence of trampling and stem base damage from cattle was confined to areas where livestock congregated, such as watering and salting areas. Extracting of stem bases from the soil appeared to be an incidental effect of grazing during periods of high soil water content.

Numerous horizontal juniper mats were partially or entirely damaged by cattle which bedded or trampled on them repeatedly. The unusually high occurrence of cattle droppings found on these mats may reflect a preference by cattle for using these sites as bedding or staging areas.

Cattle became quite sedentary during the subzero weather of late December. Rather than grazing, most livestock huddled in large groups; apparently conserving body energy. The only significant forage remaining was that associated with heavy accumulations of down litter. Forage in this condition was largely ignored by cattle. Weight loss by cattle during the final 2 weeks of the grazing treatment, although unsubstantiated by actual weighing, was visually apparent.

Fire Behavior and Weather

Conditions prior to and during spring ignitions favored a greater fire intensity than did conditions during fall burning (Tables 1 and 2). Windspeed previous to spring burns failed to meet prescription until early evening hours. Therefore, burning relied on cool-air drainage from the East Front Range rather than the warmer, drier thermal winds of mid-day. Although fuel and ambient conditions prior to spring burning were drier, using the cool-air drainage allowed for a more rapid humidity recovery and drop in ambient temperatures. Burning in fall 1983 was accomplished during day-light hours, whereas spring burning began in early evening and terminated during the early morning hours of the following day.

Table 1. Fire weather data for the fall 1983 and spring 1984 prescribed burns.

Climatological Variables	Fall	Spring
Total precipitation (cm) 30 days preceding burning	3.0	2.5
Five days preceding burning		
Mean Maximum temperature (°C)	18.3	12.1
Mean minimum temperature (°C)	- 1.1	- 2.7
Total precipitation (cm)	T	0.13
During burning		
Maximum temperature (°C)	10.0	15.5
Minimum temperature (°C)	7.2	6.1
Maximum relative humidity	50	50
Minimum relative humidity	37	27
Average wind speed (Km/hr)	8.8	3.2

Table 2. Fire behavior data for the fall 1983 and spring 1984 prescribed burns.

	Fall Burns		Spring Burns	
	Head	Backing	Head	Backing
Fine fuel moisture at ignition (%)	6.3	6.3	4.3	4.3
Fine fuel moisture at completion (%)	7.4	7.4	8.7	8.7
Flame lengths (ft)	4-6	1-2.5	4-6	1-2
Rate of spread (Chains/hr)	9.1	2.2	9.1	0.83
Fire line intensity (BTU/Ft/s)	64	nd	79	nd

nd = data unavailable for backing fires

Greater windspeeds during backing and head fires increased the rate of spread. Wind gusts often bent flames of backing fires toward previously ignited fescue clumps. The bent flames re-ignited many fescue clumps that had already been partially consumed. High moisture content within fescue stem bases reduced the severity of damage from flaming fronts, prolonged burning after passage of the flaming fronts, and increased re-ignitions from backing fires.

The sensitivity of fire temperature paints during fall 1983 burning was insufficient to detect actual temperature differences between burn types. However, the paints did allow for a general description of fire temperatures up to 12.5 cm above the soil surface. Temperatures 2.5 cm below the soil surface remained lower than 65°C for both burn types. Fire temperatures at 12.5 cm above the soil surface ranged from 145°C to 340°C for both burn types; this maximum temperature was the greatest reading that the paints were able to distinguish. Anderson (1972) found that maximum temperatures during head fires in rough fescue grasslands occur near 20 cm above the soil surface. Fescue clumps rarely smoldered longer than 15 to 20 minutes after the passage of the flaming front for either burn type. Horizontal juniper, when ignited, flared up and smoldered several hours after fire had passed over them. During fall 1983 burns, backing fires consumed several juniper plants.

An abundance of bunchgrasses within juniper mats increased the susceptibility of these juniper plants to damage by headfires. Head and backing fires during spring 1984 resulted in greater mortality to juniper plants than did fall fires. An increase in volatile substances within juniper buds immediately prior to initiating spring growth may create a more flammable condition. All true shrub species burned during fall 1983 or spring 1984 burns sprouted during the 1984 growing season with the exception of horizontal juniper (Appendix A). The prostrate, evergreen, and compact nature of horizontal juniper vegetation creates a more difficult ignition compared to the associated bunchgrasses.

Botanical Standing Crop and Composition

The grazing treatment and burn treatments caused a decrease in the total standing crop compared to the control (Table 3). This decrease was caused by the reduction of rough fescue on the grazing and burn treatments. Excluding the control, backing fires during fall 1983 and spring 1984 tended to produce greater standing crops of rough fescue and total grasses and grass-likes compared to other treatments. Extrapolation of fire behavior data suggests that backing fires burned at lower temperatures and with less intensity

Table 3. Influence of burning treatments and cattle grazing on mean litter (kg/ha), major forage species (kg/ha), and vegetation classes (kg/ha).

	Treatment					
	Control	Burn				Cattle grazing
		Fall backing	Fall head	Spring backing	Spring head	
<u>Festuca scabrella</u>	664a ⁴	391b	283b	373b	219b	278b
<u>Festuca idahoensis</u>	154a	85a	126a	139a	115a	107a
<u>Agropyron spicatum</u>	44b	75ab	73ab	60ab	70ab	104a
Misc. grasses ¹	41a	47a	69a	51a	49a	67a
<u>Carex</u> species	40a	8c	33a	12bc	10bc	28ab
Total grasses ²	944a	605b	584b	636b	464b	585b
Total forbs	268ab	261ab	232b	280ab	353a	187b
Total shrubs	14b	13b	5b	12b	5b	30a
Total standing crop ³	1221a	877b	823b	923b	825b	788b
Total standing litter	1047a	0b	0b	80b	0b	205b
Total down litter	1939a	201c	232c	1097b	301c	1602ab
Total biomass	4203a	1072c	1052c	2097bc	1123c	2584b

¹Sum of remaining grasses.

²Sum of all grasses and grass-like.

³Sum of total grasses, total forbs, and total shrub categories.

⁴Means in rows followed by a similar letter are not significantly different at (p = 0.10).

than head fires. This characteristic may have reduced heat damage to stem bases of rough fescue. The decline in rough fescue standing crop in response to fire was attributed to the heavy accumulations of down litter within the plants (Table 3). Usually, the living portion of large rough fescue plants , 22 cm to 30 cm in diameter, on the study area represented only 40 to 60 % of the plant material; the remaining portions were dead stem bases and litter. This accumulation of fine fuels prolonged combustion next to stem bases, increased fire intensity, and created a nearly continuous mat of fuels which allowed head and backing fires to blacken the majority of each burn plot. Heavy litter accumulations were absent from Idaho fescue plants. Idaho fescue produces a fine-leaved litter that appears more susceptible than rough fescue litter to rapid weathering and decomposition. Total or partial consumption of Idaho fescue root crowns by burn treatments was uncommon. These results along with reports by Antos et al. (1983) may suggest that rough fescue is more severely damaged than Idaho fescue by fire following prolonged fire-free intervals on the mesic foothill regions of Montana.

Heavy accumulations of plant litter were also absent on bluebunch wheatgrass plants. Bluebunch wheatgrass rarely assumed its characteristically vigorous bunchgrass habit on the study area. Most plants were a collective of few stems and leaves. The most vigorous bunches occurred on the loose

organic material of anthills. When fire passed over bluebunch plants, their presence was inconspicuous. Stem bases were commonly burned to a height of 2.5 cm above the soil surface.

The decrease of rough fescue standing crop on the grazing pasture may reflect the effects of trampling, stem base removal, and close grazing of those plants which retained minimal down litter. Many grazed rough fescue plants on the grazing pasture had less stubble remaining than plants which received the burn treatments. Grazing to such heights may have damaged growing points and meristematic tissue.

Standing crop of Idaho fescue, bluebunch wheatgrass, and miscellaneous grasses were similar for control and burn treatments. Idaho fescue on the burn treatments had a 5 to 7 cm stubble. The stem bases of these plants remained unburned. The grazing treatment was similar to control and burn treatments for Idaho fescue standing crop and miscellaneous grasses. The grazing treatment and control were similar for standing crop of sedges. The grazing treatment stimulated production of bluebunch wheatgrass compared to other treatments. Bluebunch wheatgrass and Idaho fescue were grazed heavily during the fall of 1983. Most leaf material of Idaho fescue plants was removed with a single bite by grazing cattle. The grazing treatment removed leaf material of Idaho fescue down to the stem base,

compared to the burning treatments which left a conspicuous amount of stubble.

The spring head fire treatment resulted in a greater standing crop of forbs than did fall headfire and grazing treatments. All other treatments were similar. The spring head fire treatment tended to produce lower total grasses and total shrub standing crop than other treatments. The reduction in grasses and shrubs may have benefitted forb species by increasing soil water available for plant growth. Fire temperature data indicated that subsoil temperatures were minimally affected by head or backing fires. Although the trend was for greater forb standing crop on controls compared to fall burn or cattle grazing treatments, actual forb composition on controls tended to be lower than other treatments (Table 4). Thus, a proportional comparison based on total vegetation production, trends indicated lower forb standing crop on controls compared to other treatments. The low forb standing crop value for the grazing treatment may partially reflect the influence of trampling on various perennial forbs. The greatest total shrub production, almost entirely fringed sage, occurred on the grazing pasture.

Total shrub standing crop was similar for all treatments excluding the cattle grazing treatment. However, head fires during spring and fall resulted in a trend of lower shrub standing crop figures compared to all other

Table 4. Influence of burning treatments and cattle grazing on plant composition (%).

Vegetation Category	Treatments					
	Control	Fall back	Spring back	Cattle Grazing	Fall head	Spring head
<i>Festuca scabrella</i>	54.4	44.4	40.4	35.0	34.4	26.7
<i>Festuca idahoensis</i>	12.6	9.7	15.0	13.4	15.3	14.1
<i>Agropyron spicatum</i>	3.5	8.5	6.4	13.0	9.0	8.5
Misc. grasses ¹	3.3	5.3	5.4	8.3	8.4	5.9
<i>Carex species</i>	3.2	0.9	1.3	3.3	4.0	1.2
Total grasses ²	77.0	68.8	68.5	73.0	71.1	56.4
Forbs	21.9	29.7	30.2	23.4	28.2	42.9
Shrubs	1.1	1.5	1.3	3.6	0.7	0.7

¹Includes grasses presented in Appendix 1 which were not individually listed above.

²Means include grasses and grass-likes.

treatments. Johnston et al.(1971) and Wright and Bailey (1982) stated that fringed sage is a primary increaser on grazed rough fescue rangelands. Thus, cattle grazing may cause an increase in fringed sage.

A primary difference between burn and grazing treatments regarding vegetation manipulation was in their effectiveness in reducing litter accumulations. Results from the initial growing season following treatments does not suggest that the heavy accumulations of litter stagnate or decrease vegetation production of this rough fescue grassland. Controls maintained a greater amount of total standing litter than all other treatments. The spring backing fire and grazing treatments left some standing litter on plants that were unburned, partially burned, ungrazed, or partially grazed. However, trampling of standing litter during the cattle treatment caused an increase in down litter. Also, standing litter and down litter that was left on the fall burn, cattle grazing, and control treatments was exposed to unmeasured removal by winds prior to spring burns. Total down litter accumulations were heavier on controls compared to fall and spring burn treatments. Controls and cattle grazing treatments were similar for down litter production. Spring backing fire and cattle grazing treatments were similar for production of down litter.

The lower soil water and temperature readings on controls during spring 1984 were influenced by litter accumulations (Appendices C and D). April was the first month of 1984 in which the study area received significant moisture. Soil water readings during the 15 June collection were taken a day following a major precipitation event (3.6cm). This amount of rainfall appeared to influence soil water levels on controls, relative to other treatments, minimally. Presence of heavy litter buildup on controls may reduce the amount of precipitation that reaches the soil surface. However, once sufficient precipitation arrives, litter may enhance the soils ability to retain soil water during extended drought periods. The moderate amounts of litter remaining on the grazing pasture were apparently inadequate to influence obvious differences in soil water or temperature compared to burn treatments. Litter on the controls probably reduced the range of diurnal temperature fluctuations compared to all other treatments. The litter accumulations on controls was a primary factor influencing the greater rough fescue production compared to the remaining treatments. Rough fescue produces the majority of its vegetative growth by late May. Precipitation during May 1984 was 5.2 cm below the 60 year norm (U.S. Weather Bureau 1984).

Elk Use

Paired plot data for elk use during spring 1984 found no significant utilization on any treatment. However, differences in numbers of rough fescue plants grazed by elk were noted for all treatments (Figure 1). Pellet group counts were similar for all treatments during spring 1984 (Figure 2). Winter conditions during 1984 were uncommonly mild. The absence of snow and subzero temperatures allowed elk to occupy higher elevation ranges normally inaccessible because of deep snows. Also, human and vehicle activity during spring burning caused an unmeasured amount of disturbance to elk. During spring 1984, elk use centered on rough fescue plants occurring on the fall burn and cattle grazing treatments. Standing litter from 1983 was unavailable to elk on fall and spring burn treatments; therefore, elk use during spring 1984 was observed on green plant material. Rough fescue plants that received light or no use by cattle received similar use by elk. Rough fescue plants that had dead standing material removed by cattle received some grazing by elk. Elk use of spring burn treatments during spring 1984 was minimal (Figure 1). The spring burn treatments caused a 7 to 10 cm portion of rough fescue leaf material to die. This dead material, which occurred above the living portion of the growing leaf, was undesirable to grazing elk. A similar leaf condition was observed on fall burned rough fescue plants, although much

Figure 1. Percent of rough fescue (FESC) plants that received grazing by elk during spring 1984 and winter-spring 1985 for all treatments.

Figure 2. Elk use days/ha for all treatments during spring 1984 and winter-spring 1985.

less severe. Elk use of rough fescue plants on controls was observed on plants that were relatively free of standing and down litter. Field observations and clipping data found trace or less elk use of forbs, shrubs, and other grasses and grass-likes. Observations of elk on the study area during spring 1984 indicated approximately 800 animals.

During the winter and spring of 1985, elk use of the study area was heavy (Figures 2 and 3). Elk use of cured 1984 leaf material from rough fescue was greater on burn and cattle grazing treatments than on controls. Elk use of rough fescue and Idaho fescue during 1985 increased compared to 1984 (Figures 1 and 4). Pellet group counts also reflected heavier elk use of all treatments in 1985 (Figure 2). Observations of elk actually on the study area were tallied from January through May. Approximately 8000 elk used the study area during this period. The majority of sightings were of the same group of elk which used the study area several days throughout the winter and spring. The highest elk count on the area previous to this study, but during a similar time span, was 1500. The winter of 1985 was characterized by consistent snow-cover and subzero temperatures. Elk migrated to the game range in November 1984. Most elk remained on the game range until May 1985. As a result, elk use throughout the game range was heavier in 1985 than use during winter-spring 1984. However, the unprecedented elk use on the study area during 1985 probably

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Figure 3. Elk use (%) of rough fescue during winter 1985 for all treatments.

¹Treatments displaying similar letters are not significantly different ($p = .10$).

Figure 4. Percent of Idaho fescue plants that received grazing by elk during winter-spring 1985 for all treatments.

corresponds with the improved forage availability and quality through the absence of litter.

Elk use of rough fescue was greatest on the burn and cattle grazing treatments (Figures 1 and 3). Elk tended to forage on greater numbers of rough and Idaho fescue plants on the burn treatments compared to all other treatments during 1985 (Figures 1 and 4). During spring 1984 and winter 1985, elk use appeared higher on fall burn plots compared to other treatments. Burn treatments supported a greater proportion of plants that were free of down or standing litter compared to the other treatments. Grazing behavior of elk on the cattle grazing and control treatments during winter 1985 simulated that of cattle grazing behavior during fall 1983. Elk removed the majority of rough fescue foliage that was unobstructed by down litter. Elk often grazed the 1984 standing litter of rough fescue which protruded through the litter clumps, leaving the remainder of the plant ungrazed. Rough fescue plants that were free of down litter had the majority of above ground leaf material removed by elk.

Controls had the highest pellet group counts compared to all other treatments (Figure 2). Thus, this elk use parameter may not be an effective tool for calculating actual elk use of an area. Elk may have preferred controls for bedding areas. Elk may have also spent longer periods on controls searching for available forage than on burn or

cattle grazing treatments.

Elk use of bluebunch wheatgrass during 1984 and 1985 was insignificant. Wintering elk prefer rough and Idaho fescue to bluebunch wheatgrass on the remainder of the game range also.

Presence of a primary access road bordering the study area apparently had minimal effect on elk use. Rather than reducing elk use, vehicle activity shifted elk use from daylight hours to predominately nocturnal feeding activity.

Plant Nutrition

Crude protein levels of rough fescue plants on burn and cattle grazing treatments were greater compared to controls for collections made on 21 April through 20 July (Table 5 and Figure 5). Rough fescue from controls had lower crude protein values than those from other treatments for all collection dates. Crude protein values for Idaho fescue plants on fall backing fire and cattle grazing treatments were greater than controls for all collection dates except 21 April, 15 June, and 25 August (Table 6 and Figure 6). Idaho fescue crude protein content on controls tended to be lower than all other treatments from May through October. Crude protein content of bluebunch wheatgrass on all burn treatments were greater than controls from May 6 through June 15 (Table 7 and Figure 7). Bluebunch plants on fall and spring headfire treatments were lower than the cattle

Table 5. Crude protein (CP) and crude fiber (CF) composition of rough fescue for all treatments and dates (expressed in percent) in 1984.

Treatment	Component	Date							
		4/21	5/6	5/20	6/1	6/15	7/20	8/25	10/7
Control	CP	7.1c	6.3d	7.0b	6.2b	6.6b	4.7b	4.3a	4.0b
	CF	67.9a	68.1a	66.4a	66.8a	68.0b	78.7a	68.2bc	71.8ab
Spring backing Fire	CP	nd ¹	14.3b	15.6a	10.1a	10.3a	7.2a	5.0a	4.9ab
	CF	nd	63.9a	63.2abc	50.3b	60.1c	60.6d	74.1a	70.5ab
Spring head Fire	CP	nd	18.8a	16.5a	12.5a	10.4a	7.5a	5.3a	5.2ab
	CF	nd	53.4b	63.2abc	65.9a	63.0bc	71.6bc	64.0c	68.0ab
Fall backing Fire	CP	16.0ab	17.9a	16.1a	11.3a	10.6a	8.0a	5.4a	5.4ab
	CF	52.2b	51.0b	60.1bc	67.3a	74.0a	71.0bc	69.1bc	70.9ab
Fall head Fire	CP	18.8a	16.4a	14.2a	9.7a	9.6a	6.9a	5.5a	5.5ab
	CF	50.5b	54.5b	59.0c	58.0b	66.4b	67.4c	71.3ab	67.4b
Cattle Grazing	CP	13.6b	11.1c	15.9a	11.4a	10.1a	8.8a	6.3a	6.3a
	CF	63.3a	66.6a	64.1ab	63.9a	67.3b	73.0b	72.3ab	72.9a

¹nd - no data available

²Means in each column followed by similar letters are not significantly different at (p = .05).

Figure 5. Mean crude protein (%) content of rough fescue for all treatments and dates in 1984.

Table 6. Crude protein (CP) and crude fiber (CF) composition of Idaho fescue for all treatments and dates (expressed in percent) in 1984.

Treatment	Component	Date							
		4/21	5/6	5/20	6/1	6/15	7/20	8/25	10/7
Control	CP	7.5c	7.2d	6.2c	6.3b	6.6b	4.8c	4.8b	4.9c
	CF	73.2a	66.1a	72.4a	62.4a	70.2a	71.7a	77.8a	73.0a
Spring backing Fire	CP	nd ¹	10.5bc	8.4b	7.1b	7.3ab	5.3bc	5.7ab	5.0bc
	CF	nd	71.1a	69.1a	69.4a	67.7a	69.4a	75.7a	67.8a
Spring head Fire	CP	nd	7.8d	7.7bc	11.0a	8.6b	6.5ab	5.2ab	5.9abc
	CF	nd	71.2a	78.1a	65.2a	69.5a	75.1a	78.9a	71.1a
Fall backing Fire	CP	6.5c	12.3a	8.9ab	10.5a	7.8ab	7.7a	6.7a	6.5ab
	CF	81.5a	69.5a	67.8a	68.5a	80.5a	67.8a	82.1a	67.8a
Fall head Fire	CP	9.4b	11.4ab	10.6a	11.2a	8.4a	5.5bc	5.8ab	5.2bc
	CF	nd	63.3a	75.2a	69.2a	68.1a	69.4a	78.4a	70.7a
Cattle Grazing	CP	11.2a	10.9abc	10.6a	10.0a	7.9ab	6.6ab	6.1ab	7.6a
	CF	69.4a	65.5a	72.9a	76.2a	75.0a	67.9a	78.8a	67.2a

¹nd - no data available

²Means followed by similar letters in columns are not significantly different at (p = .05).

Figure 6. Mean crude protein (%) content of Idaho fescue for all treatments and dates in 1984.

Table 7. Mean crude protein (CP) and crude fiber (CF) composition of bluebunch wheatgrass for all treatments and dates (expressed in percent) in 1984.

Treatment	Component	Date							
		4/21	5/6	5/20	6/1	6/15	7/20	8/25	10/7
Control	CP	6.1a	6.4c	7.1c	6.3c	5.8c	5.0b	5.0abc	4.4ab
	CF	69.9b	68.0ab	71.8a	71.5a	68.3b	69.5a	78.2ab	71.8abc
Spring backing Fire	CP	nd ²	nd	18.0b	13.2b	11.8b	6.4ab	5.1abc	3.1b
	CF	nd	nd	57.8b	56.0b	63.2b	66.7a	77.5ab	70.9bc
Spring head Fire	CP	nd	nd	19.9a	13.0b	13.3a	6.4ab	3.9bc	3.1b
	CF	nd	nd	67.0ab	60.7b	61.4b	68.9a	71.0b	77.5ab
Fall backing Fire	CP	nd	19.3a	20.6a	15.4a	13.6a	6.1ab	5.6ab	4.9a
	CF	nd	58.8b	69.7a	72.1a	78.4a	67.6a	70.5b	66.0c
Fall head Fire	CP	nd	20.0a	18.2b	13.9ab	11.2b	6.8a	3.6c	3.9ab
	CF	nd	75.6a	56.7b	56.7b	56.7b	55.4b	81.1a	81.8a
Cattle Grazing	CP	7.6a	10.7b	17.2b	13.8ab	11.1b	7.6a	5.6a	5.5a
	CF	80.7a	68.3ab	57.3b	79.0a	80.3a	71.3a	71.7ab	81.3a

¹Means in columns followed by similar letters are not significantly different at (p = .05)

²nd = no data available

Figure 7. Mean crude protein (%) content of bluebunch wheatgrass for all treatments and dates in 1984.

grazing treatment from August 25 through October 7.

The low initial protein levels of rough fescue and bluebunch wheatgrass on the cattle grazing treatment was caused by the presence of standing litter. This standing litter had a significant influence on protein levels of plants with newly emerging leaves. This influence was absent on rough fescue and bluebunch wheatgrass plants collected in the burns. Idaho fescue plants that received grazing by cattle were essentially litter-free. Cattle apparently removed all standing litter with a single bite. However, Idaho fescue plants on burn areas retained some stubble. The presence of litter within Idaho fescue plants did not lower protein levels as sharply as for rough fescue and bluebunch wheatgrass.

Generally, once these grasses emerged, the levels of protein declined as the growing season progressed. Declines were especially apparent during culm elongation. The decline in protein was less severe just prior to seed shatter and during fall regrowth (Figure 8). The trend for greater crude protein levels in rough fescue and bluebunch wheatgrass on the cattle grazing treatment occurred during the final three collection dates. Inspection of grasses during the October collection found a trend for plants that were grazed by cattle produced more tillers than plants in the burn areas. This was especially true for Idaho fescue.

Figure 8. Phenology of rough fescue, Idaho fescue, and bluebunch wheatgrass during the plant collection period 1984.

Rough fescue plants occurring on control and cattle grazing treatments were generally greater in crude fiber content than all other treatments (Table 5 and Figure 9). Crude fiber levels tended to increase as the plants matured. This gradual increase in crude fiber was associated with a reduction in crude protein content as the growing season progressed. During the first three collection dates, rough fescue plants that had the highest crude protein levels also had the lowest crude fiber content. An inverse relationship exists between crude fiber and crude protein throughout the growing season.

Crude fiber levels in bluebunch wheatgrass exhibited greater unexplained variation within collection dates than either fescue (Figure 10 and Table 7). However, similar to the fescues, crude fiber content of bluebunch plants tended to increase as the plants matured. Like rough fescue, the greatest fiber levels for bluebunch plants were found during the last three collection dates. Generally, fiber content on the control, cattle grazing, and fall headfire treatments were greater for all dates compared to all other treatments. The heavy accumulations of litter on rough fescue and bluebunch plants of controls resulted in relatively constant fiber levels throughout the collection period.

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Figure 9. Mean crude fiber (%) content of rough fescue for all treatments and dates in 1984.

Figure 10. Mean crude fiber (%) content of bluebunch wheatgrass for all treatments and dates in 1984.

Idaho fescue fiber content on all treatments was more cyclic than for rough fescue or bluebunch wheatgrass (Figure 11 and Table 6). Although crude fiber levels of Idaho fescue plants increased during boot, flower, and curing stages fiber levels were similar for the first and final collection dates. The increases in crude fiber were associated with decreases in crude protein levels during the same time periods. Tillering response of Idaho fescue during the fall regrowth period caused a decline in fiber content on all treatments.

Carbohydrate Reserves

Generally, TNC reserves of rough fescue were greatest on controls early in the growing season and greatest on the cattle grazing treatment from May through October (Table 8 and Figure 12). TNC levels of Idaho fescue were generally greater on the control and cattle grazing treatments early in the growing season and greater on the fall backing fire treatment from June through July (Table 9 and Figure 13). Fescue TNC values on controls, however, were less for the fall backing, fall head, and spring backing fire treatments from mid-June through October. TNC reserves of Idaho fescue on the spring backing fire treatment were lowest from April through 1 June compared to other treatments. An inverse relationship appears for TNC reserves for both fescues, especially those on control and grazing treatments, and soil

Figure 11. Mean crude fiber (%) content of Idaho fescue for all treatments and dates in 1984.

Table 8. Total nonstructural carbohydrate reserves (mg/g) of rough fescue for all treatments and dates.

Date	Treatment					
	Control	Spring Back	Fall Back	Spring Head	Fall Head	Cattle Grazing
4-21	91.7a	40.1c	85.4ab	59.4bc	72.1ab	72.6ab
5-6	109.7a	60.3b	78.0ab	72.1b	76.3ab	63.1b
5-20	133.8a	74.2b	72.2b	92.3b	86.7b	67.7b
6-1	117.3a	67.2b	108.2a	124.6a	102.8a	112.3a
6-15	153.1a	131.5a	140.9a	137.6a	127.7a	159.3a
7-20	158.5bc	235.5a	170.0bc	137.7c	180.5bc	188.6b
8-25	162.2c	165.4c	190.5bc	223.5ab	177.0bc	260.3a
10-7	149.6b	144.7b	204.8b	213.7a	162.3a	220.6a

¹Data in rows followed by similar letters are not significantly different at ($p = .05$).

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Figure 12. Mean TNC (mg/g) reserves of rough fescue for all treatments and dates in 1984.

Table 9. Total nonstructural carbohydrate reserves (mg/g) of Idaho fescue for all dates and treatments.

Date	Treatment					Cattle Grazing
	Control	Spring back	Fall back	Spring head	Fall head	
4-21	30.1a	17.3b	18.4b	22.2ab	22.6ab	28.1a
5-6	44.6a	24.4b	39.1a	26.9b	37.5a	38.4a
5-20	41.5ab	26.8c	35.0b	29.2c	29.7c	46.3a
6-1	46.6b	32.0c	70.3a	41.4bc	41.6ac	60.1a
6-15	39.4b	63.3a	57.0a	31.5b	41.1b	35.6b
7-20	71.7bc	73.0bc	102.4a	80.1b	51.3d	64.8cd
8-25	29.2b	37.9a	33.4ab	30.5b	22.9b	32.3ab
10-7	49.5b	59.8ab	60.4ab	68.0a	54.2ab	55.0ab

¹Data within rows followed by similar letters are not significantly different at (p = .05).

Figure 13. Mean TNC (mg/g) reserves of Idaho fescue for all treatments and dates in 1984.

water and temperature. The greater TNC levels occur on treatments that hold the lowest soil moisture readings. Perhaps carbohydrate synthesis and storage in these fescues is more favorable during conditions that discourage rapid plant growth (Appendices C and D).

Plants on the treatments initiated growth within the same week of March 1984 (Figure 8). However, spring burning caused rough fescue and Idaho fescue plants to replace the minor amount of leaf material that had already emerged. Spring burn treatments caused declines in TNC levels of Idaho fescue during the first four collection dates. By 20 July, TNC levels of Idaho fescue plants on spring burns had recovered. Spring burning had a similar influence on the TNC levels of rough fescue. However, the lower TNC values recovered by the third collection date. Rough and Idaho fescue TNC values decreased during the flowering stage. Treatments not reflecting this decline for rough fescue were associated with poor seed production. The greatest TNC levels of Idaho fescue plants during all collection dates were on 20 July (Figure 13). Idaho fescue plants were past seed shatter on that date (Figure 8). Maximum TNC levels for rough fescue occurred after seed shatter, on 20 July and 25 August (Figures 12 and 8). The variation in peak TNC levels for rough fescue is difficult to assess because phenology was similar among all treatment sites.

The study area received 3 cm of rainfall during mid-August. This was the first significant rainfall since mid-June. The enhanced soil water conditions prompted a decline in Idaho fescue TNC reserves on all treatments. Increased root growth was believed to be the primary factor contributing to the decline. TNC reserves of rough fescue declined only on the fall head fire and spring backing fire treatments. The drawdown was also less defined in rough fescue than Idaho fescue.

Idaho fescue TNC levels on all treatments recovered following the August drawdown. However, the difference between the April TNC levels and the October TNC levels appears inadequate for respiration losses during winter months. Perhaps TNC storage in root material of Idaho fescue supplements stem base storage. Fall regrowth in Idaho fescue does not appear to hamper TNC levels during the October collection. Fall regrowth may be important for increasing TNC levels of Idaho fescue prior to fall quiescence. Significant amounts of precipitation during later summer quiescence, followed by a cool fall season, may cause Idaho fescue to enter the winter with relatively low TNC reserves. The importance of root material of Idaho fescue for TNC storage is unknown. Fall regrowth in rough fescue appeared to cause declines in TNC reserves in plants on all treatments excluding the fall backing fire treatment. This inconsistency remains unexplained. Rough fescue may

expend TNC reserves during the fall to produce tillers which will resume growth the following spring. Production of tillers during fall, when TNC reserves are at a peak, may cause less energy expenditure than initiating all new growth during spring, when TNC reserves are lowest.

Organic Carbon

Soil organic carbon content was similar for control, cattle grazing, and spring burn treatments (Table 10). Organic carbon content trends for fall burn treatments were slightly below other treatments. During winter 1984, absence of consistent snow-cover allowed strong winds to erode fall burn plots. Although the entire study area was susceptible to wind, the lack of standing litter on fall burn treatments created an unprotected soil surface. Movement of soil silts and clays on fall burn treatments was visually apparent by spring 1984. Soil sediments accumulated on leeward portions of rocks and fescue rootcrowns. The scouring action of the winds removed most ash and organic matter created by fall burning. During summer 1984, raindrop impact had displaced some soil sediments onto leaves and stems of standing vegetation on spring and fall burn treatments. Trampling and hoof action on the cattle grazing pasture during fall 1983 probably incorporated much of the down litter from rough fescue into the surface soil horizon.

Table 10. Organic carbon content (%) for all treatment categories.

	Treatment Category			
	Control	Fall burns	Spring burns	Cattle Grazing
Organic Carbon Content	8.28	6.97	8.58	9.18

CHAPTER VI

SUMMARY AND CONCLUSIONS

Prescribed fire and fall cattle grazing treatments were implemented during fall 1983 and spring 1984 on a rough fescue community to reduce excessive accumulations of plant litter and increase elk use. Influences of treatments on vegetation standing crop and composition, elk use, plant nutrient content, plant TNC, and soil organic carbon content were analyzed following the 1984 growing season.

Burn treatments reduced down and standing litter and rough fescue; whereas, cattle grazing reduced standing litter accumulations and rough fescue standing crop compared to controls. Excluding controls, trends indicated spring and fall backing fires yielded greater rough fescue and total grasses standing crops compared to other treatments. The spring head fire treatment produced greater forb standing crop compared to fall head and cattle grazing treatments. Total shrub standing crop was greatest on the cattle grazing treatment. Burning and cattle grazing treatments reduced rough fescue production and increased elk use compared to controls.

Elk use tended to be greatest on the fall burn treatments during spring 1984 and winter 1985. The cattle grazing treatment also increased elk use of the study area compared to controls. Fall burn and spring headfire treatments were more effective in reducing litter accumulations than cattle grazing or spring backing fire treatments. Elk use of all treatments was directly related to the presence, or absence, of weathered down and standing litter in forage plants. The high elk use observed on the burn treatments was due to the lack of weathered plant litter rather than any detectable fertilizer effect from burning. Burning and cattle grazing treatments decreased vegetation production, yet increased forage availability and elk use. Elk use of the study area appears limited to winter and early spring. Where rough fescue plants were totally available, elk removed the majority of the 1984 standing litter during winter months and grazed newly emerging rough fescue during March and April until plants reached 7 to 10 cm in height. Elk use then shifted from the study area and onto ranges offering less advanced forage plant phenology. Elk use of rough fescue and Idaho fescue during the early spring may hamper seed production of grazed plants. However, these plants may enter fall quiescence with less structural material and higher nutrient content compared to plants that produced seed heads. Elk use during winter 1985, averaged for all burn treatments, resulted in

the removal of 83% of the 1984 standing litter from rough fescue plants compared to 66% on the cattle grazing treatment and 24% on the controls. Even though 1984 standing litter of rough fescue resembled weathered plant litter, grazing elk maintained strong aversion toward plants with down or standing weathered litter. Numerous plants on the cattle grazing treatment and controls retained large clumps of down weathered litter from which cured leaf material protruded. Elk grazed the 1984 standing litter which protruded through the down litter clump, leaving the remainder of cured leaf material within the litter clump ungrazed. Rough fescue plants resembling this condition may actually benefit from the litter clump, which reduced grazing injury to the plant. Consequently, heavy elk grazing during winter months may affect the plant community's ability to trap snow, hold soil water, and replenish soil organic matter.

Plant litter was found to have significant influences on crude protein and crude fiber content of tested grasses. The increases in crude protein content of the tested grasses was directly related to the treatments effectiveness in removing litter. Increases in plant litter tended to decrease the natural seasonal variations in crude protein and fiber of grasses. Crude protein content of burned plants was similar to plants that were entirely grazed by cattle. Increases in crude protein content of grasses were

usually associated with decreases in the crude fiber component. Grasses provided high quality forage during the early spring. During winter, grasses are a poor source of protein, but an excellent source of energy.

Generally, rough fescue and Idaho fescue plants on the burn and cattle grazing treatments maintained higher TNC reserves from mid-June through October compared to the controls. TNC reserves were found to be inversely related to soil water and temperature readings. Fall regrowth may be very important to Idaho fescue for increasing TNC reserves.

Wind erosion during winter 1984 was visually apparent on fall burn treatments. Organic carbon data indicates a possible decline in organic material on fall burns compared to other treatments. Soil silts and clays accumulated on the leeward side of rough fescue clumps and rocks on the fall burn treatments. Silts and clays were also observed on leaves and stems of standing vegetation as a result of raindrop impact on all burn treatments. Loss of surface soil particles may influence long-term productivity of these treatments.

Future Needs

Subsequent monitoring will address the status of plant litter recovery on treatment sites in relation to elk use during winter and spring. Monitoring of plant litter dynamics will aid in the development of management criteria. Future recommendations regarding acceptable litter accumulations are dependent on plant litter production, elk use, and amounts of litter required to maintain the study area in good to excellent range condition. I feel results based on a single growing season are inadequate to provide absolute management recommendations. However, future monitoring will provide the required management criteria and also further describe the influences of burn types versus season of burning on vegetation and elk use. Evaluation of plant community responses, litter recovery, soil physical parameters, and elk use may enable resource managers to plan and prescribe future treatments and experiments. Range improvement practices on the game range have increased the grazable forage supply of the area by improving forage availability and quality through litter removal. Manipulating wolfy areas into a grazable condition for wintering elk may reduce elk use of adjoining private lands and distribute elk use more evenly throughout the game range. Results from this research illustrate the need for treating an area large enough to disperse heavy use by big game and for maintaining an elk population that is in

balance with current forage supplies. Continued heavy elk use during winter and spring months may cause some decline in pre-treatment range condition. However, this was not substantiated by this study.

Replication and continual monitoring of prescribed fire and cattle grazing treatments on state-owned wildlife management areas is highly recommended. Results from this study indicate burning treatments were less costly and receive more positive trends in elk use compared to cattle grazing treatments. Prescribed fire is perhaps a more flexible alternative when budget, time, and acreage are limited. Cattle grazing may be an effective treatment under proper grazing conditions. Season and intensity of present grazing by big game are imperative considerations prior to establishing domestic livestock grazing treatments.

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Appendix A
Plant Species List

Appendix A. Plant species list.²

Grasses and Grass-likes

<u>Scientific Name</u>	<u>Common Name</u>
Agropyron smithii	Western wheatgrass
Agropyron spicatum	bluebunch wheatgrass
Aristida longiseta	red three awn
Avena fatua	wild oats
Beckmannia syzigachne	American slough grass
Bouteloua gracilis	blue grama
Bromus inermis	smooth brome
Bromus tectorum	cheatgrass
Calamovilfa longifolia	prairie sandgrass
Carex filifolia	thread leaved-sedge
Danthonia parryi	Parry oatgrass
Danthonia unispicata	one-spike oatgrass
Elymus cinereus	Basin wildrye
Festuca idahoensis	Idaho fescue
Festuca scabrella	rough fescue
Glyceria grandis	American mannagrass
Koeleria cristata	prairie junegrass
Muhlenbergia cuspidata	plans muhly
Phleum pratense	timothy
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg bluegrass
Schizachyrium scoparium	little bluestem
Stipa comata	needle-and-thread grass
Stipa viridula	green needle grass

Forbs

Scientific Name

Common Name

<i>Achillea millefolium</i>	common yarrow
<i>Allium cernuum</i>	nodding onion
<i>Anemone nuttalliana</i>	pasque flower
<i>Antennaria parvifolia</i>	nuttall's pussy-toes
<i>Arenaria capilaris</i>	fescue sandwort
<i>Artemesia ludoviciana</i>	cudweed sagewort
<i>Artemesia campestris</i>	Northern woodworm
<i>Aster falcatus</i>	creeping white prairie aster
<i>Astragalus bisulcatus</i>	two-groove milk vetch
<i>Astragalus crassicaulus</i>	buffalo plum
<i>Astragalus eucosmus</i>	elegant milk-vetch
<i>Astragalus purshii</i>	locoweed
<i>Balsamorhiza sagittata</i>	arrowleaf balsamroot
<i>Bupleurum americanum</i>	American through-wax
<i>Campanula rotundifolia</i>	scotch bluebell
<i>Castilleja lutescens</i>	yellowish paintbrush
<i>Castilleja sessiliflora</i>	downy painted-cup
<i>Centurea maculosa</i>	spotted knapweed
<i>Cerastium arvense</i>	field chickweed
<i>Comandra umbellata</i>	bastard toadflax
<i>Crepis acuminata</i>	long-leaved hawksbeard
<i>Cryptantha interrupta</i>	White forget-me-not
<i>Erigeron caespitosus</i>	tufted fleabane
<i>Erigeron ochroleucus</i>	buff fleabane
<i>Erigeron flavus</i>	yellow buckwheat
<i>Fritillaria pudica</i>	yellowbell
<i>Gaillardia aristata</i>	blanket flower
<i>Galium boreale</i>	Northern bedstraw
<i>Gaura coccinea</i>	scarlet gaura
<i>Geranium viscosissimum</i>	sticky geranium

Forbs (continued)

<u>Scientific Name</u>	<u>Common Name</u>
<i>Geum triflorum</i>	prairie smoke
<i>Glycyrrhiza lepidota</i>	American licorice
<i>Hymenoxys acaulis</i>	Hemless hymenoxys
<i>Iris missouriensis</i>	Rocky Mountain iris
<i>Lathyrus ochroleucus</i>	cream-flowered peavine
<i>Liatrus punctata</i>	blazing star
<i>Lepidium campestre</i>	field pepper weed
<i>Linum perenne</i>	wild blue flax
<i>Lithosperma incisum</i>	yellow stoneseed
<i>Lupinus sericeus</i>	silky lupine
<i>Medicago sativa</i>	alfalfa
<i>Melilotus officinale</i>	common yellow sweet-clover
<i>Microseris cuspidata</i>	toothed microseris
<i>Musineon divaricatum</i>	leafy musineon
<i>Oxytropis campestris</i>	field crazyweed
<i>Oxytropis viscida</i>	sticky crazyweed
<i>Penstemon</i> sp.	Penstemon
<i>Petalostemen purpureum</i>	purple prairie clover
<i>Potentilla arguta</i>	tall cinquefoil
<i>Potentilla gracilis</i>	gracilis cinquefoil
<i>Potentilla hippiana</i>	wooly cinquefoil
<i>Ratibida columnaris</i>	coneflower
<i>Sedum lanceolatum</i>	Lance-leaf stonecrop
<i>Senecio canus</i>	wooly groundsel
<i>Sisyrinchium angustifolium</i>	blue-eyed grass
<i>Solidago missouriensis</i>	Missouri goldenrod
<i>Solidago rigida</i>	hard-leaved goldenrod
<i>Taraxacum officinale</i>	common dandelion
<i>Thermopsis montana</i>	round-leaved thermopsis
<i>Tragopogon dubius</i>	yellow salsify
<i>Zigadensis elegans</i>	mountain death camas

Shrubs and Trees

<u>Scientific Name</u>	<u>Common Name</u>
Artemesia frigida	fringed sagewort
¹ Elaeagnus communata	silverberry
Juniperus horizontalis	horizontal juniper
¹ Potentilla fruticosa	shrubby cinquefoil
Pseudotsuga menziesii	Douglas-fir
¹ Rhus trilobata	skunkbush sumac
¹ Rosa arkansana	Arkansas rose
Spiraea betulifolia	shiny-leaf spiraea
¹ Symphoricarpus albus	common snowberry
Xanthocephalum sarothae	broom snakeweed

¹ indicates sprouting following fire

² Taxonomy follows C. L. Hitchcock and A. Cronquist, 1978

Appendix B

Location and design of burn and cattle
grazing treatments on the Sun River Game Range.

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Appendices C and D

Appendix C. Soil moisture (%) readings at 18 cm depth for all collection dates and treatments.

Date	Treatment					
	Control	Spring back	Fall back	Cattle grazing	Spring head	Fall head
4-21	23	26	31	33	32	25
5-6	14	16	21	19	23	18
5-20	19	15	19	18	20	18
6-1	8	7	8	6	10	7
6-15	27	24	20	19	27	20
7-20	nd ¹	nd	16	17	10	nd
8-25	8	6	7	5	6	5
10-7	23	21	23	18	22	20
¹ no data available						

Appendix D. Soil temperature (°C) readings at 18 cm depth for all collection dates and treatments.

Date	Treatment					
	Control	Spring back	Fall back	Cattle grazing	Spring head	Fall head
4-21	7	7	9	9	7	4
5-6	5	4	5	5	5	4
5-20	9	9	11	11	11	9
6-1	16	14	18	14	15	16
6-15	nd ¹	14	nd	nd	nd	nd
7-20	nd	nd	nd	nd	nd	nd
8-25	20	23	26	23	21	25
10-7	10	10	10	10	10	9
¹ no data available						