

AN ABSTRACT OF THE DISSERTATION OF

Patrick Eugene Clark for the degree of Doctor of Philosophy in Rangeland Resources presented on May 28, 1996. Title: Use of Livestock to Improve the Quality of Elk Winter Range Forage in Northeastern Oregon.

Abstract approved: _____

William C. Krueger

The effects of late spring defoliation on the winter forage quality of bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer) and elk sedge (*Carex geyeri* Boott) and the response of wintering Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) to changes in winter range forage quality were examined. The study included two experiments; a hand clipping experiment conducted on bluebunch wheatgrass and a sheep grazing experiment conducted on bluebunch wheatgrass, Idaho fescue, and elk sedge.

Four treatments were applied to bluebunch wheatgrass in the clipping experiment:

- 1) the entire basal area of individual plants was clipped to a 7.6 cm stubble height during the mid boot phenological stage,
- 2) one-half the basal area of individual plants was clipped to a 7.6 cm stubble height during the mid boot stage,
- 3) the entire basal area of individual plants was clipped to a 7.6 cm stubble height during the inflorescence emergence stage, and
- 4) plants were left unclipped as a control.

In early November, forage samples from each of the three clipping treatments exhibited increases in percent crude protein and percent *in vitro* dry matter digestibility compared to the unclipped control treatment.

Clipping the entire basal area of bluebunch wheatgrass plants to a 7.6 cm stubble height during the mid boot or inflorescence emergence stage was more detrimental to plant vigor than clipping one-half the plant basal area during the mid boot stage or leaving the plants unclipped. There was some evidence that clipping one-half the plant basal area during the mid boot stage may improve plant vigor compared to no clipping.

Differences in crude protein, *in vitro* dry matter digestibility, and dry matter yield from winter forage samples of bluebunch wheatgrass, Idaho fescue and elk sedge were detected between plots grazed by domestic sheep during the boot stage of bluebunch wheatgrass and plots where sheep grazing was excluded. No differences in winter elk utilization of bluebunch wheatgrass, Idaho fescue, or elk sedge were detected between the late spring sheep grazing treatment and sheep exclusion treatment. Plot occupancy by wintering elk was similar between plots grazed by sheep and plots where sheep grazing was excluded. Although, wintering elk did not appear to respond to the livestock grazing treatment, results from this study suggest small

improvements in the winter forage quality of perennial grasses such as bluebunch wheatgrass can result following late spring defoliation. Forage conditioning treatments which produce even small improvements in forage quality may be important to the nutritional status of wintering elk.

Use of Livestock to Improve the Quality
of Elk Winter Range Forage in Northeastern Oregon

by

Patrick Eugene Clark

A DISSERTATION

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Doctor of Philosophy dissertation of Patrick Eugene Clark presented on May 28, 1996

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Patrick Eugene Clark, Author

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CONTRIBUTION OF AUTHORS

Dr. William C. Krueger assisted in experimental design, logistical support, and writing of the manuscript. Dr. Larry D. Bryant assisted in experimental design and logistical support. Dr. David Thomas was involved with experimental design and statistical analysis.

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This dissertation is dedicated with love to
Teri, Reilly and Tyler

USE OF LIVESTOCK TO IMPROVE THE QUALITY OF ELK WINTER RANGE FORAGE IN NORTHEASTERN OREGON

1. INTRODUCTION

1.1 Problem Definition

A general increase in the number of Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) in western North America and a general decrease in the number of hectares of available elk winter range on public lands has occurred throughout most of this century (Bryant and Maser 1981). This paradox has contributed to increased frequency and duration of elk occupancy of private lands where elk depredation on cropland, hay stacks, and livestock pastures has become a serious problem (Vavra 1980, Nelson 1982, Lacey et al. 1993). Public desire to continue to manage for increases in huntable and viewable elk populations likely compounds this dilemma. Natural resource managers are faced with the difficult tasks of providing adequate winter forage to an increasing elk herd from already limited public winter range resources while at the same time decreasing the incidence of elk depredation on private land. This study evaluated whether prescribed livestock grazing could be used as a tool for enhancing the quality of elk winter ranges. If proven effective, prescribed livestock grazing might be useful to enhance winter range forage on public lands possibly attracting more elk to winter on public rangelands and reducing elk utilization of private rangelands. Prescribed livestock grazing could be used as an alternative to more costly winter range enhancement projects such as prescribed burning, fertilization, reseeding, and winter range purchases.

1.2 Background

1.2.1 Winter Nutritional Demands

Wintering Rocky Mountain elk require forage high enough in quality to meet the increased nutritional demands resulting from harsh and prolonged winter weather conditions (Moen 1973, Nelson and Leege 1982). The nutrient density and digestibility of forage must be high enough that rumen capacity and rate of passage do not limit the ability of an elk to meet its nutritional demands (Montgomery and Baumgardt 1965, Freer 1981, Robbins 1983, Green and Bear 1990).

Energy, protein, phosphorus, and calcium are limiting nutrients for wintering elk with energy perhaps the most important of the four (Brockway and Maloiy 1967, Nelson and Leege 1982). The primary energy

sources available in grasses are carbohydrates. These carbohydrates can be classified into two distinct forms: (1) Structural carbohydrates which are largely immobile and remain fixed in the structural components of the plant and (2) Nonstructural carbohydrates which are highly mobile within the plant and represent the major storage form of carbohydrates available to perennial grasses for growth and development (McIlvanie 1942, Cook 1966a, White 1973, Daer and Willard 1981). Most nonstructural carbohydrates (i.e., except for galactans and some oligosaccharides) are readily digestible by the gastric enzymes of ungulate herbivores (Van Soest 1982). The digestibility of structural carbohydrates is highly variable. Digestion of structural carbohydrates occurs primarily by microbial fermentation (i.e., in the rumen or lower G.I. tract) rather than by the action of gastric enzymes. Structural carbohydrates dominate an increasingly larger proportion of the total carbohydrate composition of a grass plant as the plant phenologically matures. In general, the digestibility of plant carbohydrates decreases with phenological maturity.

1.2.2 Conditioning Bluebunch Wheatgrass

Bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) is a large component of the forage base on elk winter range in the Blue Mountains of northeastern Oregon (Buechner 1952, Edgerton and Smith 1971, Anderson and Scherzinger 1975, Skovlin and Vavra 1979, Skovlin et. al. 1983, Sheehy 1987). Structural carbohydrates of grasses such as bluebunch wheatgrass represent a highly variable digestible energy source obtainable only by rumen fermentation. In contrast, total nonstructural carbohydrates (TNC) represent a readily available digestible energy source to grazing elk.

Total nonstructural carbohydrate concentrations in the roots and herbage of bluebunch wheatgrass vary with phenological development (McIlvanie 1942, Cook 1966a, Daer and Willard 1981). During winter dormancy, energy demands for respiration slowly deplete stored TNC in the roots. With initiation of spring growth, TNC reserves begin to decline more rapidly as TNC are translocated to meristematic tissue. As the early leaves grow and expand, the photosynthetic contribution of TNC from these leaves increases while the proportional contribution of stored TNC to the growth requirements of the plant decreases. Total nonstructural carbohydrate reserves continue in a sharp decline reaching an annual low just prior to the early boot stage. At this point, the photosynthetic contribution from the leaves begins to exceed demands for growth and respiration and, replenishment of the TNC reserves begins. During the early boot stage, the TNC reserves are drawn down again by the energy requirements of inflorescence development within the boot (Daer and Willard 1981). When the inflorescence has elongated to a position half way up the boot, continued leaf growth and expansion again allows photosynthetic TNC production to exceed demand and TNC storage in the roots and root crown begins to rapidly increase (McIlvanie 1942, Daer and Willard 1981). There is disagreement in the literature as to how the trend in TNC storage in bluebunch wheatgrass proceeds from this point. McIlvanie (1942) reported a general increase in TNC storage from the late boot stage to the early yellowing stage and a general decrease

during the fall curing and weathering stage. Daer and Willard (1981) observed TNC storage peaking in the late boot stage and a general decline in TNC storage following this point. Similar to TNC concentrations in the roots and root crown, TNC concentrations in the herbage of bluebunch wheatgrass exhibit a rapid increase during the boot and inflorescence emergence stages reaching a peak late in the inflorescence elongation stage and generally declining after that point (McIlvanie 1942).

It has been speculated grazing bluebunch wheatgrass in the late spring could improve forage quality by delaying the phenology of the subsequent regrowth thus preventing it from developing beyond the early seed stalk stage before low soil moisture and high temperatures induced summer quiescence (Anderson and Scherzinger 1975). If the phenological development of the regrowth is halted and the forage cures in the boot stage; TNC reserves may be high enough to prevent critical reductions in plant vigor and, herbage TNC concentrations may be substantially higher and the structural carbohydrate content substantially lower compared to phenologically mature, ungrazed plants.

Pitt (1986) observed bluebunch wheatgrass clipped to a 15 cm stubble height during the boot, inflorescence emergence, flowering, and seed formation stages delayed the phenology of the regrowth. Plants clipped at the boot stage flowered 9 to 16 days later than unclipped control plants. After two years of clipping at the boot, inflorescence emergence, flowering, and seed formation stages, acid detergent fiber (ADF) was significantly lower than in untreated plants. Crude protein showed a corresponding increase under all treatments but those plants clipped in the boot stage tended to be lower in forage quality than the other treatment groups. Pitt (1986) speculated the lower crude protein in the boot stage treatments resulted because a sufficient amount of the growing season remained after the treatment was applied that the plants regrew and matured similarly to the unclipped control plants. McLean and Wikeem (1985) suggested clipping to 15 cm of stubble height during the boot stage may not remove enough meristematic tissue to cause the plants to regrow by tillering rather replacement of photosynthetic tissue would be accomplished by continued leaf expansion.

Clipping or grazing to a lower stubble height (7.6 cm) during the boot stage might stimulate regrowth from basal apical buds if sufficient energy reserves were allowed to accumulate in the roots and root crown prior to defoliation. This would probably delay phenological development enough to provide both increased forage quality and sufficient dry matter yield for wintering elk. Hyder and Sneva (1963a) speculated defoliation of 'Whitmar' beardless bluebunch wheatgrass to 5 cm of stubble height might stimulate tillering. However, numerous studies indicate defoliation to this low a stubble height can cause decreased vigor and increased mortality if applied at a stage when root energy reserves are depleted (Hanson and Stoddart 1940, Stoddart 1946, Blaisdell and Pechanec 1949, Mueggler 1975). A more moderate stubble height (7.6 cm) might be safer and more effective in enhancing the nutritional quality of the forage.

Westenskow (1991) reported clipping bluebunch wheatgrass to 7.6 cm of stubble height during the pre boot phenological stage resulted in regrowth not significantly different in percent calcium or percent phosphorus and only slightly higher in *in vitro* dry matter digestibility during the late fall compared to an

unclipped control. Apparently, sufficient growing season remained following the pre boot clipping that the regrowth almost reached phenological maturity before summer quiescence.

The most suitable phenological stage to graze bluebunch wheatgrass to enhance the forage quality for wintering elk may be the mid boot stage. Plants grazed after the mid boot stage lack adequate growing season for sufficient regrowth. Consequently, the total quantity of nutrients available in forage conditioned under this treatment may not meet the nutritional demands of wintering elk even though the actual forage quality may be substantially increased. Grazing prior to the mid boot stage may allow the grazed plant sufficient growing season to phenologically mature completely. In terms of winter forage quality, little is gained by grazing prior to the mid boot stage. Close grazing or clipping just prior to and during the early boot stage can actually cause a substantial reduction in plant vigor because the TNC concentrations in the roots and root crown are very low during this time (Daer and Willard 1981, Mclean and Wikeem 1985). Low TNC reserves for regrowth initiation coupled with limited growing season for replacement of lost photosynthetic tissue and TNC reserves may lead to high plant mortality following early boot defoliation.

Bluebunch wheatgrass can probably tolerate defoliation to 7.6 cm of stubble height at the mid boot stage without significant reduction of plant vigor or increases in plant mortality because TNC reserves are sharply increasing in the roots and root crown during this time. Bluebunch wheatgrass plants grazed during the mid boot stage should have enough stored energy and growing season to regrow vegetatively and store enough TNC to meet the energy demands of winter respiration and spring growth initiation.

1.2.3 Conditioning Idaho Fescue and Elk Sedge

To my knowledge, the effect of prescribed livestock grazing on the winter forage quality of Idaho fescue (*Festuca idahoensis* Elmer) or elk sedge (*Carex geyeri* Boott) has not been directly evaluated.

1.2.4 Elk Selectivity for Specific Vegetation Types

What actually influences elk selectivity of specific vegetation types? Is selectivity for specific vegetation types based on the thermoregulatory constraints of the elk or is it based on forage quality or is it an interaction of several factors? Leckenby (1984) and Parker and Robbins (1984) contended elk use certain types of cover for thermoregulation. However, Peek et al. (1982) concluded, because elk have such a well-developed thermoregulatory capacity for dealing with cold weather, elk only need thermal cover during weather conditions involving a combination of extreme cold and high winds or during mid winter warming trends when temperatures may exceed an elk's ability to cool itself.

It is likely several factors influence elk selectivity of thermal cover. Elk may use thermal cover in the Blue Mountains because these areas provide moist, shaded sites where perennial graminoids such as Idaho

fescue and elk sedge remain green and more palatable longer into the winter than in more open areas.

Utilization of thermal cover by elk might be partially explained in terms of forage quality differences between open grassland and forested sites. (Pers. Comm., Larry D. Bryant, Wildlife Biologist, USDA Forest Serv. Pac. Northwest For. and Range Exp. Sta., December 16, 1991). These moister sites under the thermal cover may also prove to be critical sources of elk winter forage in years when lack of late summer and fall precipitation prevents fall regrowth from occurring on bluebunch wheatgrass-dominated ridgetops and open grasslands. Conditioning of Idaho fescue and elk sedge by prescribed livestock grazing may enhance the winter forage quality of both species by delaying phenological development. Forage conditioning of Idaho fescue and elk sedge on forested sites within an elk winter range may prove to be even more valuable than conditioning bluebunch wheatgrass (Pers. Comm., Larry D. Bryant, Wildlife Biologist, USDA For. Serv. Pac. Northwest For. and Range Exp. Sta., December 16, 1991).

1.3 Scope

The study area encompassed portions of two nearly adjacent USDA Forest Service big game winter range management areas located on the upland fringes of the 12,550 ha Starkey Basin in Blue Mountains of northeastern Oregon. Approximately 2/3 of the Starkey Basin is privately-owned rangeland used for cattle grazing. This private land primarily occupies the open grasslands of the Basin. The remaining 1/3 of the Starkey Basin is public land managed by the USDA Forest Service. The public land, including the study area, is characterized by open grassland ridgetops with forested canyons and stringer drainages. The following criteria were used in selection of this study area: 1) the topography and vegetation were typical of foothill rangelands near public/private land boundaries in the Blue Mountains; 2) the area was currently used as winter range by elk; 3) the area was located on public land simplifying logistics, and 4) the area was located near enough to Starkey Experiment Forest and Range to allow use of the automated telemetry system for tracking radio-collared elk.

This study consisted of two experiments. The first experiment was part of a series of studies (Bryant 1993; Westenskow-Wall and others 1994) conducted at this study area evaluating the effects of late spring clipping treatments on the forage quality and vigor of bluebunch wheatgrass. These clipping experiments were conducted within 0.5 ha (1 ac) livestock exclosures constructed in 1986 at two sites on the study area, McCarty Spring and Winter Ridge. The McCarty Spring exclosure was located on a gently sloping (0-5%), westerly aspect at 1,274 m in elevation. The elevation at the Winter Ridge exclosure was 1,366 m with a gently sloping (0-5%), south-southwesterly aspect. The plant community classification for both sites was bunchgrass on shallow soil, gentle slopes, GB-49-11 (Hall 1973). The dominant perennial species were bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass (*Poa secunda* Presl.) and western yarrow (*Achillea millefolium* L.). Soils at both sites were shallow, extremely stony to very cobbly, loams and silt-loams of the Anatone-Bocker complex (Dyksterhuis and High 1985; Bryant 1993).

The second experiment of the present study examined the effect of late spring domestic sheep grazing on: 1) the nutritional quality of bluebunch wheatgrass, Idaho fescue, and elk sedge; 2) winter elk utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge; and 3) winter elk distribution as determined by telemetry. This experiment was conducted in six, nearly parallel drainages near the McCarty Spring livestock enclosure used in the clipping experiment.

1.4 Objectives

The objectives of this study were:

1. Test for significant differences in the forage quality of bluebunch wheatgrass; as measured by percent crude protein, percent *in vitro* dry matter digestibility, and dry matter yield, between 4 clipping treatments (mid boot/whole plant, mid boot/half plant, inflorescence emergence/whole plant, and unclipped control) when sampled in early-November.
2. Test for significant differences in bluebunch wheatgrass plant vigor or percent mortality; as measured by percent change in basal area and percent dead to live plants, respectively, between 8 different clipping treatments (mid boot/whole plant & early November, mid boot/half plant & early November, inflorescence emergence/whole plant & early November, early November only, mid boot/whole plant only, mid boot/half plant only, inflorescence emergence/whole plant only, and unclipped control) when sampled at the hard seed phenological stage during the next growing season following treatment application.
3. Test for significant differences in the forage quality of bluebunch wheatgrass, Idaho fescue, and elk sedge; as measured by percent crude protein, percent *in vitro* dry matter digestibility, and dry matter yield, between two forage conditioning treatments (late spring livestock grazing and exclusion of livestock grazing) when sampled in early November and early March.
4. Test for statistical relationships between elk occupancy and forage utilization in the grazing experiment plots and, any of the following 11 factors suspected to influence winter elk distribution in the study area:
 - (1) Topography
 - (2) Vegetation type
 - (3) Canopy closure
 - (4) Ambient temperature
 - (5) Humidity
 - (6) Wind speed
 - (7) Radiant energy
 - (8) Snow depth
 - (9) Elk sinking depth
 - (10) Forage conditioning by livestock grazing to a 7.6 cm stubble height during the boot stage
 - (11) Exclusion of livestock grazing.

1.5 Hypotheses

1.5.1 Overriding Hypothesis

The overriding hypothesis of this study was prescribed livestock grazing (or clipping) during the mid boot phenological stage of bluebunch wheatgrass is the most effective conditioning treatment for enhancing winter forage quality, without excessively compromising the vigor or dry matter yield, of bluebunch wheatgrass, Idaho fescue, and elk sedge within the 3 dominant vegetation types present on the study area. Elk will response to the prescribed livestock grazing treatment described above by increasing occupancy and forage utilization in grazed plots compared to ungrazed plots.

1.5.2 Specific Null Hypotheses

Specific null hypotheses tested in this study were:

Ho1: Percent crude protein, percent *in vitro* dry matter digestibility, and dry matter yield of bluebunch wheatgrass will not differ among clipping treatments, locations, or years of application.

Ho2: Percent change in basal area and percent mortality of bluebunch wheatgrass will not differ among clipping treatments, locations or years of application.

Ho3: Percent crude protein, percent *in vitro* dry matter digestibility, and dry matter yield of bluebunch wheatgrass, Idaho fescue, and elk sedge will not differ among grazing treatments, canopy closure, sampling period, or years of application.

Ho4: Elk utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge will not differ among grazing treatments, canopy closure, sampling period, or years of application.

Ho5: Winter elk occupancy will not differ among the grazing treatments, blocks or years of application.

Ho6: Weather and snow cover conditions will not differ among grazing treatments, vegetation types, canopy closure, or years of application.

2. COMPREHENSIVE LITERATURE REVIEW

2.1 Historical Elk Distributions in the Pacific Northwest

2.1.1 Eastern Oregon

Archeological evidence reveals elk (*Cervus elaphus* Linn.) have occupied the Columbia Basin for approximately 10,000 years (McCorquodale 1985). Studies cited by Kay (1990) indicated ancient elk remains were present at archaeological sites in eastern Oregon, however these remains made up only a very small percentage of the total ungulate remains found at these sites. The remains of deer (*Odocoileus spp.*) and bighorn sheep (*Ovis canadensis*) were generally much more prevalent at archaeological sites in eastern Oregon than were elk remains. At archaeological sites in Elk Creek Basin of southern Oregon, Pettigrew and Lebow (1987) reported deer remains were found in human habitation layers dating back to 3,000 years ago while elk remains were found only in habitation layers which were less than 1000 years old. In three archaeological sites in northeastern Oregon, Reid (1988) noted the remains of bighorn sheep, pronghorn (*Antilocapra americana*), and bison (*Bison bison*) were present but deer and elk were absent. Notably, much of the animal remains recovered from archaeological sites in eastern Oregon have been cleaved and broken into small fragments (Minor and Toppel 1984) possibly indicating the ancient human inhabitants of these sites were attempting to extract as much food value from scarce prey resources as possible (Schmitt 1986). Reid (1988) concluded if elk were as prevalent in prehistoric northeastern Oregon as they are currently then, more elk remains should have been found at archaeological sites throughout northeast Oregon.

Early historical accounts of the elk populations in eastern Oregon are often contradictory. Some of the early explorers of the region report sightings and evidence of numerous elk. In 1812, Robert Stuart, leader of John Jacob Astor's Tonquin Expedition remarked, based on the number of shed antlers nearby, a large population of elk apparently frequented the Hot Lake area within the Grande Ronde Valley of northeastern Oregon (Rollins 1935). In 1829, Peter Skeen Ogden, chief trader in the Oregon Country for the Hudson's Bay Company, reported the headwaters of the Crooked River in central Oregon contained an abundance of elk. Captain Benjamin Bonneville, in 1834, noted large numbers of elk wintered in the Grande Ronde Valley of Oregon (Irving 1885).

Other reports seem to indicate a scarcity of elk and large game in eastern Oregon. Lewis and Clark often remarked on the lack of game animals during their travels through the Interior Pacific Northwest (Thwaites 1969). In 1832, John Ball, a member of Nathaniel Wyeth's first expedition considered the sighting of fresh elk tracks along the Powder River of northeastern Oregon noteworthy after finding little evidence of game since leaving the "buffalo country" (Oregon Historical Society 1902). Narcissa Whitman noted, in 1836, the

Cayuse Indians of northeastern Oregon and southeastern Washington used camas roots rather than meat from game animals as their primary winter food (Evans 1990).

These contrasting reports appear to indicate elk were not evenly distributed throughout eastern and central Oregon during pre-settlement time. From an ecological standpoint, an uneven distribution of elk in eastern Oregon is not surprising. Elk have been classified as mid seral species and consequently, are typically found in higher numbers in areas which are rebounding from disturbance. In eastern Oregon, during pre-settlement times, the disturbance most likely to influence elk distribution was fire. It is quite possible that those early travelers who reported a scarcity of elk in eastern Oregon had passed through areas that would have been classified as transitory elk range where the vegetation was at the wrong end of the fire cycle to be attractive to elk. (Pers. Comm.: Martin Vavra, Eastern Oregon Agricultural Research Center, September 6, 1994). In 1805, Lewis and Clark noted elk and deer were difficult to find in the Selway River area of Idaho. Large amounts of "fallen timber" (possibly indicative of a dense, stagnated forest) were also mentioned by Clark while in this area (Thwaites 1969). However, after the fires of 1910, elk and deer numbers in the Selway area increased considerably (personal communication: Martin Vavra, Eastern Oregon Agricultural Research Center, September 6, 1994).

During the great westward emigration along the Oregon Trail in the mid 1800s, elk were frequently seen by settlers in eastern Oregon (Bailey 1936). However, by the late 1880s, the combined effect of unregulated hunting, heavy livestock grazing, and tillage of the native grasslands nearly caused the extirpation of elk in the Blue Mountains of Oregon (Irwin et al. 1994). Regulated elk hunting was imposed in Oregon in 1904. The following year, elk hunting was banned within the state. In 1907, the total elk population in Oregon was estimated to be 200 head (Seton 1927). Hunting of Rocky Mountain elk (*Cervus elaphus nelsoni*) in eastern Oregon remained illegal until 1933 (Mace 1971). To augment the remaining population of Rocky Mountain elk in eastern Oregon, translocations of elk from Jackson Hole, Wyoming and Yellowstone National Park to northeastern Oregon were conducted in 1912 and 1913 (Bailey 1936, Couch 1953, Bryant and Maser 1982). Bailey (1936) reported there was an estimated total of 710 head of elk living in Baker, Umatilla, Union, and Wallowa counties of northeastern Oregon in 1916. Based on information from Bailey (1936) and Shay (1954), Irwin et al. (1994) concluded the total Rocky Mountain elk population in the Blue Mountains of Oregon and Washington probably numbered less than "a few thousand animals in the 1920s". However, by 1932 there were an estimated 3,000 head of Rocky Mountain elk in Wallowa county alone (Couch 1953). Elk hunting was reinstated in eastern Oregon in 1933. During the decades of the 1940s, 50s, and 60s the number of hunters and the number of harvested elk in eastern Oregon generally increased. During the decade of the 1970s, elk populations in eastern Oregon swelled by 45% (Edwards 1992). By 1976, the estimated Rocky Mountain elk population for eastern Oregon was 60,000 head (Bryant and Maser 1982). Irwin et al. (1994) reported the Rocky Mountain elk population for Baker, Umatilla, Union, and Wallowa counties was estimated at 58,500 head in 1980. During the winter of 1993, the Oregon Department of Fish and Wildlife estimated the

Rocky Mountain elk population in eastern Oregon totalled 61,400 (person communication: Tom Thornton, Oregon Dept. of Fish and Wildlife. August 23, 1994).

2.1.2 Eastern Washington

As noted above, elk have been present in the Columbia Basin, including eastern Washington, for the last 10,000 years (McCorquodale 1985). Kay (1990) evaluated data from several archaeological studies and reported elk remains were found in 38 of the 58 archaeological sites in the Columbia Basin region of Washington. The ungulate remains at most of these sites were dominated (76%) by deer remains. Elk remains represented only 5% of the total ungulate remains found at these sites. As with the ungulate remains found at eastern Oregon sites, most of the ungulate remains found at eastern Washington archaeological sites was high fragmented. Olson (1983) noted even the mandible and phalanges were cracked open to extract the marrow. Marrow extraction from these bones is highly labor-intensive and evidence of this type of processing may be indicative of food or meat scarcity (Binford 1978, Olson 1983).

Historical accounts regarding the Rocky Mountain elk population in eastern Washington are apparently not as numerous as those of eastern Oregon. Rocky Mountain elk were probably unevenly distributed throughout the Blue Mountains of Washington, portions of northeastern Washington, and to a limited extent, the Columbia Basin region of Washington (McCorquodale 1985, Kay 1990). Human presence and activities probably strongly influenced elk distribution in and around commonly used travel routes and settlement areas of eastern Washington. As in eastern Oregon, elk were nearly extirpated from eastern Washington in the late 1880s as a result of resource over-exploitation (Bryant and Maser 1982). Washington state outlawed elk hunting in 1905 (Brown 1967). Seton (1927) estimated that the total elk population in Washington was 1,500 head in 1907. Elk hunting was outlawed in eastern Washington until 1927 (Couch 1953). Translocations of elk from Yellowstone National Park to Pomerory and Walla Walla, Washington occurred in 1913 (Bailey 1936). In 1918 and 1931, elk were translocated from Yellowstone National Park to Walla Walla and Dayton, Washington, respectively (Couch 1953). Rocky Mountain elk populations in eastern Washington generally increased until the late 1970s. In 1979, the Rocky Mountain elk population in eastern Washington was reported as "stable" at an estimated 24,000 head (Washington Department of Game 1979). In the spring of 1994, the population estimate for Rocky Mountain elk living in eastern Washington was 25,000 (personal communication: Rolf Johnson, Washington Dept. of Wildlife. August 26, 1994).

2.1.3 Idaho

Kay (1990) reported archaeological sites in the eastern Snake River Plains contained primarily bison remains while ungulate remains from sites in the western Snake River Valley are predominantly bighorn sheep and deer. Of 15 Idaho sites examined only 5 contained elk remains accounting for only 1% of the total remains recovered.

Historical accounts of the elk distribution in Idaho are contradictory. After crossing over the Bitterroot Divide into Idaho in 1805, Lewis and Clark noted no elk and only a few deer were killed by their hunters. Humbird (1975) suggested, historically, elk were distributed throughout most of Idaho but the most dense population occurred in the mountains of the eastern portion of the state. During pre-settlement times, elk were probably not abundant in the northern, panhandle region of Idaho (Bryant and Maser 1982). Seton (1927) described all of Idaho except the extreme southwestern corner as being "primitive" or historical elk range. As with eastern Oregon, these contradictions concerning the historical distribution of elk in Idaho suggest elk were unevenly distributed throughout Idaho possibly in response to fire disturbance patterns (personal communication: Martin Vavra, Eastern Oregon Agricultural Research Center, September 6, 1994).

Following the discovery of gold in Pierce, Idaho in 1860, the elk population in Idaho began to decline (Bryant and Maser 1982). Seton (1927) estimated the elk population of Idaho in 1907 was 5,000 head. In 1926, following the exploitative era of the late 1800s and early 1900s, the distribution of elk in Idaho was limited to a narrow strip, including the Bitterroot Mountains and the Upper Salmon River, in the eastern portion of the state (Seton 1927).

Translocations of elk from Yellowstone National Park and Jackson Hole, Wyoming to various areas within Idaho occurred between 1915 and 1946 (Humbird 1975). Elk were eventually re-established in 40 of the 44 counties of Idaho. In 1976, the Rocky Mountain elk population was estimated to be 51,000 head (Bryant and Maser 1982). In 1994, the Idaho Department of Fish and Game did not calculate formal population estimates for Rocky Mountain elk in Idaho. Instead, bull to cow and calf to cow ratios were used as indices of elk population status. In 1994, elk herds within 34 of approximately 60 big game management units had bull to cow ratios ranging from 15 to 25 bulls per 100 cows. Management units in the Upper Snake River area supported calf to cow ratios of 55 calves to 100 cows (personal communication: Lloyd Oldenberg, Idaho Dept. Fish and Game. September 16, 1994).

2.2 Livestock and Elk: Habitats

2.2.1 Evaluation Methods for Habitat Utilization

There are various methods commonly used by researchers to quantify habitat use by animals. This section describes the evaluation methods for habitat utilization used in the literature cited in this review.

Direct observation: Generally involves establishment of observation routes or view points as part of the experimental design. From these observation routes or view points, the animals are observed, either with aided or unaided eye, and their locations relative to identified habitat types are recorded. Often the behavior (feeding, resting, social, alert, and ect.) of the animals is also noted. The location and behavior data can then be used to evaluate the frequency and duration of animal occupancy and animal activity within different habitat types. Use of direct observation to assess habitat use allows the researcher to visually confirm animal locations and associated activity. Also, individual animals may be identified by markings, horn configuration, radio-collars, or ear tags and their habitat use patterns can individually be recorded. However, the validity of the observation data is limited by completeness of the observational coverage in space and time. Logistics (man-power, expense, travel time, available daylight and equipment requirements) may limit the completeness observation coverage. Additionally, this method may be biased if the animals are aware of the presence of the observer.

Fecal group counts: Usually entails the establishment of belt transects or plots within each habitat type to be studied. Counts of pellet-groups or cow chips encountered in the transects or plots are tallied and used as an index of animal occupancy within the sampled area. The habitat use indices used with this method are usually based on the documented daily defecation rate for the animal species being studied. Generally, a specific number of encountered fecal groups is considered to be equivalent to one day of animal use given the defecation rate of that species. This method is less labor-intensive and, consequently, less expensive to use when compared to the direct observation method. However, the application of this method is limited by the tendency for animals to defecate more often while doing certain activities than while doing others. Consequently, if an animal spent equal amounts of time in two different habitat types but, defecated more in one habitat type than the other because the activities that the animal conducted in each habitat were different, then the habitat use results would be biased towards the habitat where the animal conducted activities which were associated with higher defecation rates. Additionally, the fecal group count method currently cannot be used to evaluate animal activity within different habitat types as can the direct observation method.

Forage utilization: Involves estimation of forage consumption compared to forage availability within each habitat type being studied. Forage consumption is most often assessed by the ocular estimate by plot method (Pechanec and Pickford 1937) or by comparison of the forage weight between paired plots where one

plot is excluded from animal use (caged) while the animals are allowed free access to the other plot. The forage utilization method provides a way to evaluate habitat use by foraging animals. However, this method does not allow evaluation of habitat use by animals involved in other activities (resting, social, traveling, and ect.) besides foraging. Additionally, in situations where different animal species are consuming the same forage species in the same areas, it may not be possible to evaluate the habitat use of each animal species using this method.

Radio-telemetry: Generally includes equipping wild or tame animals with radio-collars to enable relocation of these animals at specified time intervals once they are released and allowed to roam freely throughout the habitat types being studied. The radio-collared animals are generally relocated using triangulation of radio signals from two or more vantage points. The accuracy of this triangulated location may be all that is required for some studies. However, in many studies, once the general location of a radio-collared animal is obtained through triangulation then, an attempt is made to get a visual conformation of the location of the animal and the activity the animal is engaged in. Consequently, the radio-telemetry method often involves direct observation methodology as well. The applicability of the radio-telemetry method is limited by some of the same biases as the direct observation method and by its relatively high expense as well.

Time-lapse photography: Entails establishment of time-lapse cameras at vantage points chosen to maximize the practical field of view of each camera and to provide the most complete coverage of the habitat types to be studied. The duration of occupancy of an individual animal within a specific habitat type can be evaluated by reviewing how many consecutive photographic frames contain the animal within a particular habitat. The frequency which an individual animal or animal species used a particular habitat can be evaluated by counting the number of frames containing a specific individual or species within that habitat type. The activities an animal was engaged in while in the different habitat types can also be determined by reviewing the photographic frames. Given infrared and starlight photography technologies, it is possible to gather animal location and activity data day or night at whatever collection interval the researcher chooses. However, the applicability of this method is limited by the relatively high cost of the cameras, labor-intensity of the photo interpretation, and the limited practical field of view of these cameras. In large study areas containing several habitat types of interest, it may be logistically impractical to obtain statistically adequate camera coverage of the area, especially if the habitat types contain dense vegetation or undulating topography. The time-lapse photography method is probably most applicable in open habitats such as riparian meadows, open forest on level terrain, and grasslands.

2.2.2 Cattle: Abstract of Preferred Habitats

Cattle (*Bos taurus*) prefer grassland, open forest, and clearcut forest habitats when foraging and rarely use dense forest habitats except when resting during harsh climatic conditions. Seasonally, cattle use of uplands generally begins to decline in mid summer while use of riparian zones increases. Cattle use in riparian zones

peaks in late summer. In some cases, cattle shift habitat use from the riparian areas back to the uplands during late summer and early fall. Cattle make similar or heavier use of riparian zones in the late season pastures of deferred-rotation grazing management systems compared to cattle use of riparian zones in pastures of continuous grazing management systems. Increases in stocking rate can provide more even distribution of cattle throughout a pasture of variable topography. Cattle generally avoid slopes of greater than 20%. However, the presence of trails, logging roads and other access improvements generally allows cattle to climb and traverse steep slopes more readily but any increases in cattle use on steep slope are usually limited to short distances away from the access improvements. Levels of success in altering cattle distribution on rangelands with strategic location of water developments and salt have been highly variable.

2.2.3 Cattle: Preferred Summer and Fall Habitats

Based on forage utilization and direct observation, Roath and Krueger (1982) determined cattle exhibited a preference for bluegrass (*Poa spp.*) meadows over other habitats on a forested range in the southern Blue Mountains of Oregon during summer. Eighty-one percent of the forage eaten by cattle on the study area came from the bluegrass meadows.

On a cattle allotment within the watershed of the Middle Fork of the John Day River in Oregon, Gillen et al. (1984) used direct observation and forage utilization sampling techniques to evaluate summer habitat use by cattle. They reported cattle exhibited a strong preference ($P < 0.05$) for meadow communities under both continuous and deferred-rotation grazing management. Preference for meadow communities among the 2 grazing systems was highest in the late season pasture of the deferred-rotation system. Logged forest communities were preferred ($P < 0.05$) by cattle while in the early season pasture but no preference for these communities was exhibited by cattle in the late season pasture of the deferred-rotation system. Mixed conifer communities and ponderosa pine/Douglas-fir (*Pinus ponderosa/Pseudotsuga menziesii*) communities were used less than their availability ($P < 0.05$) by cattle under the deferred-rotation system. Although cattle did not exhibit a preference for the ponderosa pine/Douglas-fir communities, nearly 1/4 of the cattle use in the early and late season pastures of the deferred-rotation system occurred in these communities. Ponderosa pine/Douglas-fir communities were used according to their availability in the continuously grazed pasture. Cattle in the continuously grazed pasture avoided ($P < 0.05$) the mixed conifer and grand fir (*Abies grandis*) communities. Cattle use of the grand fir community group was not studied in the deferred-rotation pastures.

While studying summer forage utilization by cattle within grassland, forest, and clearcut forest habitats in the foothills of the Wallowa Mountains of Oregon, Miller and Krueger (1976) noted although seeded clearcuts represented only 31% of the study area, forage from the clearcuts made up 63% of cattle summer diets. Orchardgrass (*Dactylis glomerata*) and timothy (*Phleum pratense*) made up 55% of the diet of

cattle grazing in the clear cuts. Forested areas represented 41% of the study area while only 8% of forage consumed by cattle came from forested areas.

In the foothills of southeastern Wyoming, Hart et al. (1991) used direct observation to assess habitat use by cattle. They noted cattle preferentially used the lowland areas on the study area over the upland areas despite changes in stocking rate from very light (0.034 AUM/ha) to moderate (0.28 AUM/ha). At the very light stocking level, cattle made almost exclusive use of the most productive loamy and shallow loamy range sites. Increased stocking rates resulted in more even use of the study area. Distance traveled from water increased with stocking rate. Use of steep slopes also increased with stocking rate and seasonal progression.

On a foothill rangeland in southwestern Montana, Marlow and Pogacnik (1986) directly observed and recorded cattle behavior and habitat use. They reported cattle use of upland range decreased steadily from mid summer until fall while use in riparian zones increased. During early July, cattle foraged and rested significantly ($P < 0.05$) more in the uplands than in the riparian zones. However, by late August, significantly ($P < 0.05$) more observations of feeding cattle were made in the riparian zones than in the uplands.

Gillen et al. (1985) used time-lapse photography to study cattle use of riparian meadows within the watershed of the Middle Fork of the John Day River in northeastern Oregon. They concluded total cattle occupancy and frequency of cattle occupancy in riparian areas was less in pastures grazed during the early period (early June to early August) of a deferred rotation system than in a pasture which was continuously grazed from early June to mid October. Grazing during the late period (early August to mid October) resulted in levels of total cattle riparian occupancy which were similar to those found in the continuously grazed pasture. However, late season grazing tended to increase the frequency of cattle occupancy in the riparian meadows when compared to continuous grazing. Cattle use of riparian meadows was highest during the afternoon hours regardless of the grazing system used.

While directly observing cattle use of riparian and upland habitats within the Starkey Experimental Forest and Range of northeastern Oregon, Bryant (1982) noted, both in pastures with predominantly southerly aspects and in pastures with northerly aspects, cow-calf pairs and yearling cattle exhibited a preference for riparian habitat over upland habitat during mid summer but shifted their preference to the upland habitat during late summer and early fall. While in the uplands during late summer, cattle preferred to occupy the forested plant communities more than the grassland communities. During early fall, yearlings and cow-calf pairs used different plant communities within the upland habitat. Cow-calf pairs tended to make more even use of the pastures than did yearlings. Both yearlings and cow-calf pairs preferred slopes of less than 35%. Neither distance from free water or distance from salt appeared to influence cattle distribution within the pastures.

Miller and Krueger (1976) reported the distance from water and salt could be used to explain 79% of the variability in forage use by cattle. Inclusion of soil depth and canopy closures factors allowed for 99% of the variability in use to be explained. Slopes on their study area rarely exceeded 15%. Consequently, slope was not a factor affecting cattle distribution within this study. They concluded strategic location of clearcuts and water

and salt sources could be used to manipulate cattle distribution to meet a broad range of management objectives on forested rangelands of low to moderate relief.

Roath and Krueger (1982) noticed only 62% of the variability in forage utilization on their study area could be accounted for by distance to water and salt. However, multiple regression analysis on the water and salt distance factors was confounded by the vegetation type.

Gillen et al. (1984) reported while distances from water or salt had no significant effects, slope gradient was negatively associated with cattle distribution under both the continuous and deferred-rotation grazing systems. Cattle preferred slopes of less than 10%, especially in the late season pasture of a two pasture, deferred-rotation system. Cattle exhibited an aversion to slopes of greater than 20% during all seasons of use.

Pinchak et al. (1991) observed 79% of cattle use occurred on slopes of less than 7% and areas within 366 m of water sources received 77% of the use by cattle. Based on cow chip counts, Mueggler (1965) noted 81% of the variability in cattle use patterns on bunchgrass rangeland in southwest Montana could be explained by the steepness of slope and the distance up slope from canyon and draw bottoms. In northern Utah, Cook (1966b) measured 21 possible factors influencing cattle distribution on slopes. Regression analysis of these 21 factors explained only 52% of the variability in use.

Roath and Krueger (1982) reported on moderate to steep slopes the vertical rise from water explained 94% and 82% of the variation in utilization of bluebunch wheatgrass and basin wildrye (*Elymus cinereus*), respectively. However, on gentle slopes a trail distance from water model could probably have replaced the vertical rise model for predicting cattle use of upland species. They also noted on steep terrain, logging roads and skid trails received considerable use by cattle as travel routes. Roads appeared to allow cattle to use forage in steep terrain that normally would not have been utilized. In rugged areas, cattle use of forage decreased rapidly with increased distance from roads. Use of access improvements as a method to improve livestock distribution on rugged rangelands was also discussed by Williams (1954) and Workman and Hooper (1968).

2.2.4 Sheep: Abstract of Preferred Habitats

In general, habitat use by sheep (*Ovis aries*) on open rangelands is strongly influenced by the management practices of the sheep herder. Desiring to fatten lambs, a herder may concentrate the sheep in areas where he or she believes the best lamb feed exists. In the face of heavy predation, the sheep may tend to remain in the open rather than venturing into forested areas. The sheep herder may also bed the sheep near the camp to minimize night losses to predators. Use of different elevational zones and the vegetation types associated with those zones is largely dependent on the sheep herder and the camp rotation schedule. However, despite these human-imposed controls on sheep habitat preference, the literature does identify some "natural" use patterns of sheep in different habitat types.

2.2.5 Sheep: Preferred Summer and Winter Habitats

In the Elkhorn Mountains of western Montana, Stevens (1966) observed sheep heavily used the open park habitat in the high elevation spruce/fir zone during summer. He noted the sheep were herded to and from the open parks. Mature lodgepole pine (*Pinus contorta*) stands were used as resting areas during midday.

Warren and Mysterud (1991) used radio-telemetry to evaluate summer habitat use of domestic sheep on forested range in Norway. Sheep used meadow/old field and spruce (*Picea abies*) forest habitats significantly ($P < 0.01$) more than their availability. Spruce/blueberry (*Picea abies/Vaccinium myrtillus*) and pine/heather/lichen (*Pinus sylvestris/Calluna vulgaris/Cladonia spp.*) habitats were used less than their availability. Time of day was significantly ($P < 0.01$) related to summer habitat use by sheep. Use of meadow/old field and spruce forest habitats occurred during the morning and early afternoon. The spruce/blueberry and pine/heather/lichen habitats were used during the evening and at night.

Open areas which were higher than the surrounding topography were preferred bedding areas for sheep. These areas were apparently desirable because they provided good visibility allowing early detection of approaching predators (Warren and Mysterud 1991). Based on pellet group counts, McDaniel and Tiedeman (1981) reported sheep in New Mexico preferred open ridgetops as bedding areas during winter. They also noted unherded sheep tended to use the same bedding area night after night.

Warren and Mysterud (1991) observed sheep habitat use varied significantly ($P < 0.01$) with the progression of the summer grazing season. Use of the meadow/old field habitats was relative high during the early portion of the grazing season but declined as the season progressed. Conversely, sheep use of the forest habitats increased as the season progressed.

McDaniel and Tiedeman (1981) noted steep slopes did not preclude winter use by sheep. However, the amount of forage utilization by sheep on slopes steeper than 45% was 55 to 75% less than the forage utilization of more gentle slopes. Ridgetops were preferred as foraging areas by sheep. The aspect of the slope and the distance of an area from water did not significantly influence the distribution of sheep in this study.

2.2.6 Elk: Abstract of Preferred Habitats

In montane areas, elk generally use upland grassland habitats as spring and fall range. Small openings of upland grassland habitat are preferred by elk over large openings. Elk prefer to use riverine (riparian) forest, old-growth grand fir, mixed conifer stringer, and wet meadow habitats during the summer with elk use of these habitats peaking during late summer and early fall. Canyon grassland habitats are usually avoided by elk between June and September. Logging disturbance can have variable effects on elk habitat use. In general, elk use decreases in open habitats such as clearcuts and grasslands and increases in habitats containing hiding

cover during and, for a variable amount of time, after human disturbances. Summer and winter elk home ranges generally contain a cover to forage ratio of 40% cover habitats to 60% foraging habitats.

In shrub-steppe areas, cow elk prefer rolling topography and riparian areas during the spring, especially during the calving period. Cow elk tend to increase the use of flat terrain as the season progresses. Peak use of flat terrain by cow and bull elk occurs in the fall. Shallow drainages are preferred as bedding sites by cow elk throughout the spring and most of the summer. Shrub stands serve as preferred bedding sites for cow elk during the late summer and fall. Cow elk generally remain close (< 1 km) to free water sources during times of hot weather.

2.2.7 Elk: Preferred Seasonal Habitats

Thomas et al. (1979) recommended that optimum habitat for elk in the Blue Mountains of Oregon and Washington should be defined as land area having a ratio of 40% cover habitat types and 60% foraging habitat types where potable water is within 0.8 km of any point in the land area. Directly observing radio-collared elk in the Blue Mountains of Oregon, Leckenby (1984) noticed that cover-to-forage ratios within summer elk home ranges averaged 56%. Elk made preferential use of cover in home ranges where the cover-to-forage ratio was less than 35%. Increases in the cover-to-forage ratio resulted in smaller home range sizes during summer. Winter elk home ranges contained an average of 40% cover. During winter, home range size did not vary with the cover-to-forage ratio.

In northeastern Oregon, Pedersen et al. (1980) reported the Douglas-fir/grand fir-dominated, upland mixed forest habitat type served as summer foraging and resting areas, travel routes, and hiding and thermal cover for radio-collared elk. The upland mixed forest type was used by elk slightly more during the night than during the day. Elk use of the upland mixed forest type increased as summer progressed and peaked in September.

The old-growth grand fir habitat type was highly preferred during the summer, providing travel routes, resting areas, thermal cover, and wallows for radio-collared elk. Human disturbances increased elk use of this habitat type. The old-growth grand fir type was also preferred for night bedding sites by elk. Like the upland mixed conifer type, use of the old-growth grand fir habitat type increased as summer progressed (Pedersen et al. 1980).

The old clearcut habitat type (10 years or more since timber harvest) was primarily used by radio-collared elk for foraging but it was not a preferred habitat type. Forage utilization was highest during late summer and early fall. Use of the old clearcuts declined with human disturbance (Pedersen et al 1980).

The upland grassland habitat type was used during the spring and fall for foraging. This was the first habitat type used by radio-collared elk returning from lower elevation winter ranges. Elk preferred small

openings of the upland grassland habitat over large openings. Night use of this type often exceeded day use (Pedersen et al. 1980).

The north slope conifer habitat type served as water sources, foraging areas, travel routes and, thermal and hiding cover. This habitat type represented 27% of the study area. Radio-collared elk used this habitat type in proportion to its availability. Day and night use of this habitat type were approximately equal. Use of the north slope conifer type remained at a relatively constant level throughout the summer with some decrease in use occurring in September. Human disturbance did not appreciably affect use in this habitat (Pedersen et al. 1980).

The canyon grassland habitat type was used the least by the radio-collared elk in this study. Elk use of this habitat type was always proportionally less than its availability. Night use of this habitat type generally exceeded day use. The canyon grasslands were used primarily in the late spring and fall as foraging areas (Pedersen et al. 1980).

The mixed conifer stringer habitat type was highly preferred and served as travel routes, foraging areas, and hiding cover for radio-collared elk. This habitat type was of limited value as thermal cover. During this study more elk locations were found in this habitat type than in any other. Elk use of the mixed conifer stringer type was high in early to mid summer, then decreased in late summer, and finally peaked in early fall. Human disturbance resulted in decreased use of this habitat type (Pedersen et al. 1980).

The riverine (riparian) forest habitat type was the most preferred habitat type by radio-collared elk in this study. This habitat type provided, forage, water, thermal and hiding cover, travel routes, bedding sites, and wallows. This habitat type apparently served as cover for elk attempting to evade human disturbance. Use of the riverine forest type was generally high throughout the season (Pedersen et al. 1980).

Elk use of the new-logged area habitat type increased with time after the logging disturbance. One area within this habitat type was highly preferred by radio-collared elk on the third year following the end of logging activity. Day use exceeded night use in this habitat type. This habitat type was primarily used for foraging but there was some indication it also provided some thermal cover. Elk use of the new-logged area habitat type was highest in late summer and early fall (Pedersen et al. 1980).

Working with radio-collared elk in the shrub-grasslands of south central Washington, McCorquodale et al. (1986) found during spring, late summer, and fall cow elk selectively used lower elevation sagebrush (*Artemisia tridentata*) communities. Riparian communities were preferred in the fall and, for calving and lactation during the late spring. Cow elk used rolling terrain significantly more ($P < 0.05$) than other available terrain on the study area during the spring. Cow elk were observed on flat terrain 28% of the time during the summer and 54% of the time during the fall. For all seasons, except during the calving period, more than 75% of cow elk observations occurred in the flat or rolling terrain. Foothill terrain received 56% of the cow elk observations during the calving period. Bulls did not exhibit a topographic preference during spring and summer but preferred ($P < 0.05$) flat areas (56% of observations) and avoided ($P < 0.05$) foothills (only 9% of observations) during the fall.

Cow elk preferred to bed in gullies or shallow drainages during the spring (72%), calving (86%), and summer (61% of observations) periods. Bedding occurred on flat terrain for 51% of the fall cow elk observations. Sagebrush stands were preferred for resting/ruminating during late summer and fall. It was suggested that elk were taking advantage of the more favorable microclimate created by the shading of the sagebrush (McCorquodale et al. 1986).

Cow elk use near springs and free water sources increased with ambient temperature. Most cow elk observations occurred within 1 km of free water sources during the mid summer. Use of riparian areas by cow elk increased between sundown and sunrise. Bull elk also tended to remain close to free water sources during the summer but, were occasionally observed at least 18 km from known water sources (McCorquodale et al. 1986).

Collins et al. (1978) directly observed the distribution patterns of tame elk within segments of lodgepole pine habitats in northern Utah. They reported tame elk preferred wet and dry meadows, clearcuts, and reseeded logging roads for grazing while wet meadows, reseeded logging roads, and mature forest were preferred for bedding and resting. Comparison of preference quotients for each habitat segment indicated the wet meadows were highly preferred over the other habitat segments for both foraging and resting.

Irwin and Peek (1983) reported nonmigratory, radio-collared elk in northern Idaho did not exhibit a significant preference for habitat type, successional stage, canopy closure, elevation, or distance to an opening. However, elk winter home ranges selectively included southwesterly aspects.

During the spring, radio-collared elk tended to feed in the grass-shrub and shrub seral communities within the grand fir habitat type. Most of the elk use within the grass-shrub and shrub seral communities occurred in areas: 1) having less than 25% canopy closure, 2) having less than 650 trees/ha, 3) having shallow slopes or ridges, 4) within 200-400 m of water, and 5) within less than 200 m from large openings (>1 ha). During the spring, elk were generally rested in tall brush fields or in stands of pole timber where the trees were less than 12 m tall and had 50 to 75% canopy closure. Resting areas were: 1) higher in elevation than the feeding areas, 2) on westerly aspects or on ridgetops, 3) greater than 400 m from traveled roads, and 4) less than 200 m from large openings (>1 ha) (Irwin and Peek 1983).

The seral shrub communities within the grand fir/myrtle pachistima (*Abies grandis*/*Pachistima myrsinites*) habitat type were often used by feeding radio-collared elk during the summer. Elk tended to rest on ridges during the summer in stands of pole timber which were greater than 400 m from traveled roads and had 50 to 75% canopy closure (Irwin and Peek 1983).

Irwin and Peek (1983) found fall habitat selection by radio-collared elk differed from spring and summer. Elk tended to feed and rest in similar areas during the fall. Pole timber in the western hemlock/myrtle pachistima (*Tsuga heterophylla*/*Pachistima myrsinites*) habitat type was used more than its availability while the grand fir/myrtle pachistima and the subalpine fir (*Abies lasiocarpa*) types tended to be avoided. Within the western hemlock/myrtle pachistima type, elk made disproportionately high use of ridgetops and rarely used

south slopes. Increased road traffic apparently caused elk to almost always remain greater than 400 m from roads and between 400 and 600 m from large openings (>1 ha).

2.2.8 Livestock and Elk: Habitat Overlap

Using pellet-group counts as an index for elk days of use in the Blue Mountains of northeastern Oregon, Skovlin et al. (1968) reported elk did not exhibit a preference between forested areas (mean of 0.65 elk use days/ha) and openings (mean of 0.53 elk use days/ha). They also noted cattle spent approximately half their time in grassland habitats and half in forested habitats. Increased cattle stocking on dual-use (cattle and big game) ranges resulted in increased big game use of grassland habitats but the overall big game use of moderately and heavily stocked dual-use ranges decreased. Elk spent significantly ($P < 0.05$) more time on big game-only ranges than on dual-use ranges. Higher availability of ungrazed forage was suggested as the factor that attracted elk to the big game-only ranges.

Yeo et al. (1993) directly observed cattle and elk from a fixed-wing aircraft while studying the seasonal habitat selection response of these ungulates to a rest-rotation cattle grazing management system in the steep terrain of east central Idaho. During summer-fall, cattle made increasingly greater use of high elevations ($P = 0.0001$) and steep slopes with each successive year after the rest-rotation system was implemented.

In summer-fall, elk use of riparian and forested habitats was nearly twice as high in the pastures grazed by cattle as in the rested pastures. Elk did not use the riparian habitats in either the grazed or rested pastures during winter. Winter elk use of the forested habitats was higher in the grazed pastures than in the rested pastures. During spring, elk made similar use of the riparian habitats in the grazed and rested pastures but did not use the forested habitats in the grazed pastures (Yeo et al. 1993).

Working on a ponderosa pine-bunchgrass range in central Arizona, Wallace and Krausman (1987) noticed sightings of elk along an observation route were significantly ($P < 0.05$) lower in pastures which were being grazed by cattle than in pastures where cattle were absent. Habitat use by elk shifted from open forest-grassland and logged areas in pastures without cattle to heavily forested areas when cattle were brought into a pasture.

Stevens (1966) reported direct observations of elk on his study area in the Elkhorn Mountains of Montana indicated nearly 100% of elk winter use and 90% of elk early spring use occurred in a habitat zone dominated by Idaho fescue and bluebunch wheatgrass. Early summer elk use was more evenly distributed across the three habitat zones (fescue/wheatgrass zone, Douglas-fir zone, and Engelmann spruce/subalpine fir zone) identified on the study area. Later in the summer elk tended to prefer the higher elevation, Engelmann spruce/subalpine fir zone.

Three cattle allotments were located in the Elkhorn Mountains study area. Two of these allotments occurred in the fescue/wheatgrass and the Douglas-fir zones while the third, higher elevation allotment occurred in the Douglas-fir and Engelmann spruce/subalpine fir zones. Cattle grazing on the lower two allotments occurred from June to mid October. During early and late day feeding periods cattle tended to use the fescue/wheatgrass zone and were concentrated in fescue/wheatgrass and sagebrush/fescue vegetation types. The aspen/willow (*Populus tremuloides/Salix spp.*) vegetation type, located in the drainage bottoms of the fescue/wheatgrass zone, was used by cattle for resting during the heat of the day. Cattle foraging in the Douglas-fir zone occurred primarily in the grass/forb park vegetation type while the aspen/willow and Douglas-fir vegetation types were used for resting. Cattle grazing in the higher elevation allotment occurred from July to mid September. Cattle used the Engelmann spruce/subalpine fir zone almost exclusively during that time. The grass/forb park was the most preferred vegetation type for cattle foraging. Cattle used the mature lodgepole vegetation type for resting (Stevens 1966).

Sheep used the Elkhorn Mountains study area between mid July and late August. The sheep were herded according to a camp rotation schedule, feeding from park to park within the Engelmann spruce/subalpine fir zone. Resting occurred primarily in the mature lodgepole vegetation type (Stevens 1966).

In the foothills of southeastern Wyoming, Hart et al. (1991) reported little overlap in habitat use between cattle during the summer and elk during the winter. Cattle preferred to utilize the gentler terrain while elk used the more rugged uplands.

Based on their findings about elk food habits during severe winter weather in northeastern Oregon, Skovlin and Vavra (1979) advised that forage allocation strategies should designate open ridges and upper south slopes for big game winter use and management activities which promote cattle use of upper slopes may be undesirable on big game winter ranges.

2.3 Livestock and Elk: Diets

2.3.1 Evaluation Methods for Ungulate Diets

There are various methods commonly used by researchers to study the diet of herbivores. This section describes the diet analysis methods used in the literature cited in this review.

Bite count: Involves observing foraging herbivores and counting the number of bites taken from different forage species. Tame animals are most often used so the observer can remain close enough to the foraging animals that accurate bite counts can be made. Use of tame animals also allows the observer to collect simulated bites of the forage species that the animals are foraging on. The simulated bite samples can then be used to evaluate, on a species basis, the amount of forage by weight the animals consumed. Diet quality analysis procedures can also be conducted on these simulated bite samples. The bite count method for diet

analysis in tame animals depends on the assumption that tame animals, foraging in a particular areas, will have the same diet as the wild animals foraging in the same area. The diet experience and previous handling received by the tame animals can influence their diet selection, thus introducing bias into the results. However, conducting bite counts with wild animals, in order to avoid the potential bias associated with the use of tame animals, is logistically difficult. Bite counts on wild animals must be conducted from a distance vantage point in order to avoid disturbing the foraging animals. Determining bites on individual forage species is often difficult even with the aid of powerful binoculars or spotting scopes. Collection of accurate simulated bite samples while conducting bite counts on wild animals is usually very difficult. Consequently, bite count data on wild animals allows determination of foraging time spent consuming specific species but, not the amount (weight) of each forage species consumed. Despite its limitations, bite count methodology can prevent valuable information on the diet composition, foraging behavior, and foraging efficiency of free-ranging ungulates.

Esophageal fistulation: Allows collection of ingested food samples for use in evaluating diet composition. To minimize stress-related complications associated with invasive surgery and close handling of the study animals, tame animals are normally used for this technique. A fistula is surgically installed in the esophagus of the study animals. The animals are allowed to forage in the study area. After an acclimation period, forage samples are taken from the collection bag attached to the fistula. Plant epidermal fragments in the fistula samples are identified to species using microhistological (Sparks and Malechek 1968) techniques. The frequency of plant fragments for species is used to determined percent of the diet represented by each species. Samples collected via esophageal fistula are subjected to only a limited amount of digestion (i.e., salivary enzymes). Consequently, unlike fecal and rumen analysis techniques (described below), the esophageal fistulation technique is reasonably free of biases caused by differential digestion rates between forage species. However, as with the bite count method, the esophageal fistulation method may be biased by factors associated with the use of tame animals rather than wild animals.

Fecal analysis: Entails collection of fecal samples and use microhistological techniques to determine the frequency of plant epidermal fragments from each forage species in the herbivore diet. The frequency data is then used to determine the percent of the diet represented by each species. The fecal analysis method of diet determination generally over-estimates the dietary percentage of graminoids, which contain substantial proportions of indigestible material, while under- estimating the dietary percentage of highly digestible forb species. The accuracy of fecal analysis for determining the browse content of the diet is variable between browse species. Vavra and Holechek (1980) reported the percent of snowbrush ceanothus in hand-compound samples was highly over- estimated while common snowberry (*Symphoricarpos albus*) was under-estimated when fecal analysis was used to determine the composition of the samples. They suggested when microhistological analysis is used for diet determination, regression equations should be developed to correct for differential digestibility between forage species in the diet (Vavra and Holechek 1980).

Foraging site examination: Generally consists of identifying foraging sites by direct observation of foraging animals and then using forage utilization techniques to evaluate diet composition. The percent

utilization by weight for each forage species is expressed as the dietary percent for each species. It should be noted that utilization sampling only at identified foraging sites may introduce bias into the results. For example, use of this method may result in over-sampling of open habitats where foraging animals are more observable while under-sampling habitats with heavier cover where animals are less observable.

Forage utilization analysis: Can be accomplished by two basic methods; the ocular estimate by plot method outlined by Pechnac and Pickford (1937) or by comparison of caged and uncaged paired utilization plots. The utilization by weight percent is used as an expression of the percent of the diet represented by each forage species. Unlike the foraging site examination method, the area examined with the forage utilization method is not limited to identified foraging sites. Forage utilization sampling is usually conducted at randomly located sampling points. Consequently, any bias associated with sampling location should be eliminated by randomization. However, the forage utilization method can be very labor-intensive. In large study areas with a diverse variety of habitats and associated forage species, it may be logistically difficult to obtain a statistically valid data set of forage utilization on a habitat by habitat basis. Additionally, since the species of herbivore foraging at each sample point is not visually confirmed when using the forage utilization analysis, it may be difficult to determine the diets of individual herbivore species in areas which are occupied by more than one herbivore species at any one time.

Rumen analysis: Involves collection and analysis of rumen content samples from harvested or sacrificed animals. In some older studies, the rumen was opened and a grid frame was positioned over the rumen contents. The frequency of identifiable plant fragments within each grid section was ocularly evaluated and recorded. In more recent studies, rumen samples are collected and microhistological analysis is conducted on the samples to determine the dietary composition. Under-estimation of the dietary contribution of highly digestible forage species and inherently small sample size are the primary limitations of rumen analysis.

2.3.2 Cattle: Abstract of Seasonal Diets

Cattle diets are the most diversified during the spring. The forb content in the diets of cattle grazing in both, forested and grassland habitats is generally higher during the spring than during any other season. Consequently, the diets of cattle grazing in early season (late spring-mid summer) pastures of a deferred-rotation grazing system tend to be more diversified than do cattle diets in late season (mid summer-early fall) pastures.

The summer diets of cattle grazing in grassland habitats are made up of almost exclusively graminoids. Graminoids also dominate the summer diets of cattle grazing in forested habitats. Increases in cattle stocking rates tend to increase the utilization of perennial grasses. The utilization of the perennial grasses compared to other available forage species tends to be higher in late season pastures than in early season pastures of deferred-rotation grazing systems. In forested habitats, cattle use of perennial grasses tends to decrease with increasing tree density. Browse use by cattle in forested habitats may increase slightly in late

summer as the palatability of the perennial grasses and forbs decreases. However, fall cattle diets are generally almost exclusively made up of graminoids.

Comparison of cattle diets on rangelands of different condition classes indicates the dietary composition is partially dependent on forage availability. On rangelands in good condition, having nearly a full complement of perennial grasses, summer cattle diets tend to contain almost entirely graminoids. On degraded rangelands, where much of the perennial grasses have been replaced by weedy forbs, summer cattle diets tend to contain a relatively high percentage of forbs.

2.3.3 Cattle: Seasonal Diets

In the Starkey Experimental Forest and Range in northeastern Oregon, Skovlin et al. (1976) reported, based on ocular estimates of forage utilization, the summer diets of cattle grazing in bunchgrass-dominated grasslands contained 96% graminoids while graminoids formed 88% of cattle diets from forested areas. Elk sedge was the most prominent forest graminoid species in cattle diets. Bluebunch wheatgrass dominated cattle diets in the grasslands.

In 1948, Pickford and Reid (1948) theorized that as range conditions improved on the then depleted rangelands of the Starkey Experimental Forest and Range, the percentage of graminoids in cattle diets would increase. This theory is supported by a comparison of cattle diet composition (72% graminoids) in the Pickford and Reid (1948) study with the Skovlin et al. (1976) study during which the range conditions on the Starkey Experimental Forest and Range were fair to good.

Also working on cattle summer range in northeastern Oregon, Miller and Krueger (1976) evaluated forage utilization by cattle using paired exclosed (caged) and unexclosed plots. They reported 63% of the total forage consumed by cattle came from logged forest habitats. Seeded grasses made up 55% of the forage utilized by cattle in the logged forest habitats. Forage from bunchgrass-dominated grasslands made up 29% of the total forage utilized by cattle. Sandberg bluegrass and bluebunch wheatgrass were the predominant forage species utilized by cattle while in the grassland habitats. Only 8% of the total forage utilized by cattle came from forested habitats.

Clary et al. (1978) reported forage utilization estimates indicated perennial grasses formed 97% of the summer cattle diet on ponderosa pine-bunchgrass range in northern Arizona. They also noted 75% of the variability in forage utilization could be explained by the combination of two variables; perennial grass production and ponderosa pine density (basal area/ha). Forage consumption increased with increased perennial grass production and decreased ponderosa pine density. In southeastern Washington, Lauer (1983) noted, based on cow chip counts, cattle use of forested habitats decreased with increased tree density.

Holechek et al. (1982a) reported based on forage samples collected from esophageally-fistulated cows, Idaho fescue, bluebunch wheatgrass, and Sandberg bluegrass were the most prominent species in summer cattle diets on grassland habitat in the Blue Mountains of Oregon. Idaho fescue was preferred over

bluebunch wheatgrass. Sandberg bluegrass was the most abundant grass on the study area but was utilized much less than its availability. Forage preference in cattle was related to plant phenology. The diversity of cattle diets was higher during late spring than during the rest of the grazing season. Forbs made up as much as 41% of the late spring cattle diet. Important forbs were western yarrow, arrowleaf balsamroot (*Balsamorhiza sagittata*), and lupine (*Lupinus spp.*). As the forbs matured in early summer, cattle diets switched to an almost complete dominance of grasses. Late summer and fall diets continued to contain almost exclusively grasses. Browse consumption remained relatively static, ranging from 3 to 8% of the diet throughout the grazing season.

In forested habitats of the Blue Mountains, Holechek et al. (1982b) noted cattle forage samples collected via esophageal fistulas indicated Idaho fescue and elk sedge were the primary items in cattle diets during the summer grazing season. Forbs made up as much as 36% of late spring cattle diets. Important forbs were western yarrow, heartleaf arnica (*Arnica cordifolia*), and lupine. Forb use declined with seasonal and phenological progression. Browse use increased as the palatability of graminoids and forbs decreased. Common snowberry, spirea (*Spirea spp.*), and wax currant (*Ribes cereum*) were the most common browse species in the diet.

Using fecal analysis techniques, Sheehy (1987) reported summer cattle diets in foothill bunchgrass and ponderosa pine-bunchgrass communities in northeastern Oregon consisted of 67% perennial grasses, 15% annual grasses, 6% grasslikes, 6% half-shrubs and forbs, 1% trees, and 5% other. Dominant perennial grasses in the diet were Kentucky bluegrass (*Poa pratensis*) (24%), bluebunch wheatgrass (19%), and Idaho fescue (17% of the summer diet). Elk sedge was the most important grasslike species making up 3% of the summer diet.

Fall cattle diets in the foothills of northeastern Oregon contained 87% perennial grasses, 1% annual grasses, 1% grasslikes, 5% half-shrubs and forbs, 1% trees, and 5% other. Bluebunch wheatgrass (46%) was the most prominent perennial grass in the fall diet followed by Idaho fescue (36%). Hoods phlox (*Phlox hoodii*) (4%) was the most important forb in the diet (Sheehy 1987).

2.3.4 Cattle Diets: Stocking Rates and Grazing Systems

In the Starkey Experimental Forest and Range in northeastern Oregon, Skovlin et al. (1976) reported the utilization of primary grass species by cattle was positively ($P < 0.05$) related to cattle stocking rates. Shrub and forb use were not significantly affected by stocking rates. Overall forage utilization was not significantly different between season-long and deferred-rotation grazing management systems. However, utilization of bluebunch wheatgrass was 6% higher ($P < 0.05$) on season-long ranges than on deferred-rotation ranges. Loss of quantity and quality in the early maturing annual grasses and forbs possibly explained why cattle made heavier use of the principal forage species on the late season ranges as compared to the early season ranges of the deferred-rotation system.

2.3.5 Sheep: Abstract of Season Diets

Spring sheep diets in lower elevation montane habitats are dominated by graminoids with forbs playing a secondary role in the diet. In low elevation shrub-steppe habitats, spring sheep diets may contain considerable amounts of browse. Graminoids dominate sheep diets in lower elevation montane habitats during the summer but forbs are the principal summer dietary component in higher elevation meadow and parkland habitats. The availability of palatable forbs can influence dietary composition as the grazing season progresses. Sheep tend to increase their consumption of graminoids as the available forbs mature and desiccate. Additionally, the consumption of forbs by sheep decreases with each successive visit to a particular feeding site. Summer sheep diets may be dominated by browse species in forested habitats containing a high proportion of palatable browse but limited amounts of herbaceous forage.

2.3.6 Sheep: Seasonal Diets

On a degraded, high elevation rangeland in northeastern Oregon, Pickford and Reid (1943) reported forage utilization estimates indicated summer sheep diets consisted of 66% forbs, 33% graminoids, and 1% browse. Knotweed (*Polygonum spp.*), lupine, hawkweed (*Hieracium spp.*), Gray ligusticum (*Ligusticum grayi*), and littleflower penstemon (*Penstemon procerus*) were the most prominent forbs in the diet. Major graminoid species were subalpine needlegrass (*Stipa columbiana*), elk sedge, and other sedges (*Carex spp.*).

Hanley and Hanley (1982) noted, based on fecal analysis, spring sheep diets in northeastern California and northwestern Nevada consisted of 47% graminoids, 12% forbs, and 41% browse. Summer sheep diets contained 68% graminoids, 22% forbs, and 10% browse.

In western Montana, Stevens (1966) reported feeding site evaluations indicated summer sheep diets were dominated (70%) by forbs. The major forb species in the diet were pale agoseris (*Agoseris glauca*), lupine, and hawkweed. Graminoids formed the remainder of the summer diet. Sedges, bromes (*Bromus spp.*), danthonias (*Danthonia spp.*), and wheatgrasses were the most important graminoids. Dietary differences were apparent between the first and subsequent visits by sheep to a feeding area. During the first visit the forb content of the diet was usually higher (as much as 89% of the diet) than in subsequent visits. Graminoids increased in the sheep diet with the number of visits to a feeding area.

On pumice soils in south central Oregon, Stuth and Winward (1977) noted, based on forage utilization estimates, summer sheep diets in meadow communities contained an average of 81% graminoids and 19% forbs. Diets in the logged lodgepole pine/antelope bitterbrush/western needlegrass (*Pinus contorta*/*Purshia tridentata*/*Stipa occidentalis*) community were made up of 74% browse (primarily antelope

bitterbrush), 24% graminoids, and 2% forbs. Summer diets in the unlogged lodgepole community consisted of nearly 100% antelope bitterbrush browse.

2.3.7 Elk: Abstract of Seasonal Diets

Elk winter diets are generally dominated by graminoids. However, the winter elk diet composition appears to be related to the type and quantity of forage available on each particular winter range. On winter ranges dominated by graminoids, the graminoid content of late winter-early spring elk diets tend to be higher than the graminoid content of late fall-early winter diets. The graminoid content of late season elk diets consists primarily of green growth. Graminoids also dominate the spring elk diet. During the summer, elk tend to shift to a forb dominated diet. However, summer elk diets in subalpine-alpine habitats often exhibit an graminoid dominance. In the fall, elk generally shift from a forb preference back to a graminoid preference. On fall ranges where the vegetative composition is dominated by browse species, fall elk diets tend to be composed primarily of browse.

2.3.8 Elk: Seasonal Diets

Skovlin and Vavra (1979) used microhistological techniques to evaluate winter elk diets from pellet collections made in early winter (December 1973) and in late winter-early spring (March-April 1974) on winter ranges within five different big game management units in northeastern Oregon. Idaho fescue was the most prominent species in winter elk diets. On three of the five management units the highest consumption of Idaho fescue by elk occurred during the late season. Early and late season elk diets contained 43% and 77% grasses, respectively. Grasses in late season elk diets were primarily green, new growth. Dietz and Nagy (1976) and, Vavra and Sneva (1978) also noted grasses predominated big game diets during the late winter-early spring. Skovlin and Vavra (1979) reported elk use of forbs was minimal during both the early and the late season. Browse species made up only 5% of the winter elk diet. It should be noted big game winter ranges in northeastern Oregon lack the extensive shrub communities common to other big game winter ranges throughout the West (Skovlin and Vavra 1979). However, since the results of this study were based on fecal analysis without adjustment for differential digestibility of dietary constituents, the role of browse and forbs in the winter elk diet may have been under-estimated while the role of graminoids may have been over-estimated.

Sheehy (1987) used fecal analysis to study winter elk diets in foothill bunchgrass and ponderosa pine-bunchgrass communities in northeastern Oregon. Perennial grasses formed 50% of the diet while grasslikes made up 30%, half-shrubs and forbs 5%, trees 8%, shrubs 2%, and other forage 5%. The most prominent perennial grasses in the winter diet were Idaho fescue and bluebunch wheatgrass, each made up 21% of the diet. Elk sedge was the dominant grasslike forming 30% of the diet. The half-shrub Oregon grape (*Berberis*

repens) constituted 4% of the winter diet. Ponderosa pine was the only tree browsed and formed 8% of the diet. Antelope bitterbrush made up 2% of the elk winter diet. Sheehy (1987) used *in vitro* digested, hand-composited diet samples to correct for differential digestibility of dietary components in the fecal analysis results.

Based on analysis of fecal and rumen samples, Sheehy (1987) reported spring elk diets in the foothills of the Blue Mountains of Oregon consisted of 65% perennial grasses, 15% grasslikes, 4% half shrubs and forbs, 5% trees, 1% shrubs, and 9% other forage. Two perennial grasses, Idaho fescue and bluebunch wheatgrass formed 30% and 19% of the spring elk diet, respectively. Elk sedge made up 15% of the diet. Oregon grape was the dominant half shrub-forb consumed by elk forming 2% of the diet. Ponderosa pine made up 5% of the spring elk diet.

Using fecal analysis methodology, Korfhage et al. (1980) noted during the late spring, elk diets in northeastern Oregon contained mostly graminoids (60%). As the season progressed into summer, elk increased their consumption of forbs while decreasing their graminoid intake. Forb and browse use peaked during late summer, averaging 46% and 41% of the diet, respectively. The principal grasses in elk summer diets were bluebunch wheatgrass, mountain brome (*Bromus marginatus*), elk sedge, orchard grass, and sheep fescue (*Festuca ovina*). Dominant forbs in elk summer diets were American trail plant (*Adenocaulon bicolor*), Oregon falsebugbane (*Trautvetteria grandis*), and Columbia monkshood (*Aconitum columbianum*). Oceanspray (*Holodiscus dumosus*), mallow ninebark (*Physocarpus malvaceus*), and Pacific yew (*Taxus brevifolia*) were the most common browse species in the summer diets. The differential digestibility of dietary components was not accounted for in this study.

Kufeld (1973) reviewed 48 elk food habit studies which had been conducted in different areas throughout the western United States. The seasonal composition of elk diets were summarized as both, percentages of 3 major forage groups; browse, forbs, and graminoids, and by ranking the prominence of individual forage species in elk diets. Kufeld (1973) concluded elk winter dietary composition was strongly influenced by forage availability. Elk wintering on grasslands in Montana had diets which consisted of 63 to 100% grasses, with browse and forb content averaging 9% and 8%, respectively (Casagrande and Janson 1957, Morrison and Schwartz 1957, Greer 1959, Constan 1967, Gordon 1968, and Greer et al. 1970). In Montana and portions of northern Idaho and northeastern Washington, elk winter diets consisted of 65% grasses, 2% forbs, 15% browse, and 5% lower plants (DeNio 1938). In Jasper Park, Alberta, elk wintered almost entirely on grasses with 97% of their diet coming from that forage group (Cowan 1947). In New Mexico, Manitoba, Colorado, and Idaho, browse constituted 95% (Lang 1958), 62% (Blood 1966), 57% (Boyd 1970), and 82% (Trout and Leege 1971) of elk winter diets, respectively. Elk use of grasses in the 4 studies just mentioned averaged 22% with little or no use of forbs (Kufeld 1973).

Eight Montana studies reviewed by Kufeld (1973) indicated elk spring diets included an average of 87% grasses (Morris and Schwartz 1957, Rouse 1957, Kirsch 1963, Stevens 1966, Eustace 1967, Gordon 1968, Greer et al. 1970, and Mackie 1970). Up to 1973, the only acceptable spring elk diet data available

outside of Montana came from a Manitoba study (Blood 1966) where elk diets contained 54% grasses, 37% browse, and 9% forbs (Kufeld 1973).

Based on feeding site examinations, Stevens (1966) reported grasses made up 77% of spring elk diets in the Elkhorn Mountains of Montana. Idaho fescue was the most dominant grass in the diets. Forbs formed the remaining portion of the diet. As spring progressed, elk diets tended to increase in forb content.

Forbs were the most important forage group during the summer for elk in Montana. Kufeld (1973) compared the findings of 7 Montana studies and found elk summer diets included 64% forbs, 30% grasses, and 6% browse (Morrison and Schwartz 1957, Rouse 1958, Kirsch 1963, Stevens 1966, Eustace 1967, Greer et al. 1970, and Mackie 1970). Two Colorado studies, Nichols (1957) and Boyd (1970) reported grasses were the most important summer elk forage making up 58% and 78% of elk summer diets, respectively. Young and Robinette (1939) in Idaho and Blood (1966) in Manitoba both found browse formed the largest portion of elk summer diets, 55% and 52%, respectively (Kufeld 1973).

Working on alpine-subalpine summer ranges in Rocky Mountain National Park, Colorado, Baker and Hobbs (1982) reported, based on bite count analysis, tame elk diets consisted primarily of graminoids. The amount of graminoids in elk diets remained similar ($P > 0.31$) throughout the summer rather than changing with the phenological progression of the available forage species. Elk summer diets contained similar ($P > 0.11$) quantities of graminoids between the 3 habitat types on the study area: 1) willow park type, 2) Krummhotz ecotone type, and 3) alpine tundra type. Within the willow park type; sedges, baltic rush (*Juncus balticus*), tea-leaved willow (*Salix planifolia*), and blueberry dominated elk summer diets. Elk primarily fed on sedges, tea-leaved willow, short-fruited willow (*Salix brachycarpa*), kobresia (*Kobresia myosuroides*), and tufted hairgrass (*Deschampsia caespitosa*) in the Krummhotz ecotone type. Elk diets in the alpine tundra type were dominated by sedges, rush, tufted hairgrass, tea-leaved willow, alpine avens (*Geum rossii*), and elkslip marshmarigold (*Caltha leptosepala*).

Collins et al. (1978) used bite count techniques to study the summer diets of tame elk in lodgepole pine habitats of northern Utah. Forbs were the most prominent forage group in the elk summer diets followed by grasses with browse being of limited importance.

In his review, Kufeld (1973), found elk in Montana tended to shift from forbs to grasses in the fall. Data for elk fall diets from 9 Montana studies indicated grass constituted an average of 73% of diet (Rush 1932, Morrison and Schwartz 1957, Rouse 1957, Greer 1959, Greer 1960, Kirsch 1963, Peek 1963, Greer et al. 1970, and Mackie 1970). In the only Colorado study reviewed which contained fall diet data (Boyd 1970), grasses formed 92% of the fall elk diet. Fall diets were apparently quite variable between different areas of New Mexico. Burt and Gates (1959) noted fall elk diets contained 84% grass while Lang (1958), also in New Mexico, reported browse formed 77% of the fall diets and grasses only 21%. In areas of Manitoba (Blood 1966) and Idaho (Young and Robinette 1939), browse use was also high reaching 55% and 40%, while forbs reached 37% and 40%, and grasses 8% and 20%, respectively (Kufeld 1973).

Using data from the elk diet studies he reviewed, Kufeld (1973) calculated dietary prominence rankings for each forage species identified in the review. Bluebunch wheatgrass, sedges, elk sedge, Idaho fescue, rough fescue (*Festuca scabrella*), prairie junegrass (*Koeleria cristata*) principal grass species in elk diets. Dietary importance varied seasonally for most of the graminoids just mentioned. Only elk sedge and prairie junegrass were ranked as "highly valuable" and "valuable" year-round forages, respectively. Pale agoseris and sticky geranium (*Geranium viscosissimum*) were the important forbs in summer elk diets. Lupine was noted as a highly preferred fall forb. Aster (*Aster spp.*) was found to be an important year-round forage. Serviceberry (*Amelanchier spp.*), red stem ceanothus (*Ceanothus sanguineus*), snowbrush ceanothus (*Ceanothus velutinus*), quaking aspen (*Populus tremuloides*), common chokecherry (*Prunus virginiana*), antelope bitterbrush, Gambel oak (*Quercus gambelli*), and willows were "highly valuable" browse species for elk (Kufeld 1973).

2.4 Livestock and Elk: Diet Overlap

2.4.1 Livestock and Elk: Abstract of Diet Overlap

Summer cattle diets and winter elk diets are the most likely to substantially overlap. However, in areas containing both cattle summer range and elk winter range, cattle summer range is typically higher in elevation and spatially distant from elk winter range. Consequently, it is unlikely overlaps will occur between both, the diets and the habitats used by cattle during the summer and by elk during the winter. However, as discussed later in this review, the combination of habitat and diet overlap between these two ungulates is more likely to occur on fall cattle range which is often used by elk later in the year as winter range.

The greatest overlap between the diets of elk and domestic sheep occurs during the summer when both species rely heavily on forbs. However, elk tend to be more selective among forb species than are sheep. Elk are also inclined to remain on a forb-dominated diet throughout the summer. Conversely, the amount of forbs in the summer diets of sheep generally decreases as the season progresses while the amount of graminoids and browse generally increases.

2.4.2 Livestock and Elk: Seasonal Diet Overlap

Using fecal analysis to study the diets of cattle and elk in the foothills of the Wallowa Mountains in northeastern Oregon, Miller and Vavra (1982) noted Idaho fescue and bluebunch wheatgrass were important winter dietary components of both mule deer (*Odocoileus hemionus*) and elk. Idaho fescue and bluebunch

wheatgrass also formed a major portion of the summer diets of cattle grazing on big game winter and spring range.

Kasworm et al. (1984) reported the summer diets of cattle grazing on a big game winter range in north central Montana exhibited significant ($P < 0.05$) positive Spearman's Rank correlations with early winter elk diets ($r_s = 0.63$) and with late winter elk diets ($r_s = 0.50$). Wheatgrasses and fescues were common forages in both summer cattle diets and in early and late winter elk diets.

Also working in Montana, Stevens (1966) noted, based on feeding site examination, forbs made up 76% of the summer elk diet. Graminoids constituted only 17% of the elk diet and were believed to be consumed incidentally while elk foraged on forbs. The remainder of the summer elk diet consisted of browse. Forb use decreased while browse use increased as the season progressed. Summer diets of cattle consisted of 75% graminoids with forbs forming most of the remaining portion of the diet. Summer sheep diets were dominated by forbs (70%) while graminoids were of secondary importance and browse forming only a minor portion of the diets. The percentage of grasses in sheep diets increased between the first and the second visits to individual parks. It appeared the grazing done by sheep during the first visit to a park decreased the availability of forbs forcing the sheep to increase the percentage of grasses in their diets during the next visit to the park.

Working on a degraded rangeland in northeastern Oregon, Pickford and Reid (1943) compared the forage species utilized by sheep during the summer to those utilized by elk after the sheep had been excluded from the rangeland for 2 years. They found diet similarities were evident between elk and sheep. Forbs growing in wet meadows were heavily used by both species. Mesic sedges were also common in both diets. On dry upland sites, elk sedge was also used by both elk and sheep. However, the potential for strong competition between sheep and elk was moderated by the foraging selectivity exhibited by elk within forage groups. Elk tended to be more selective between forb species than sheep.

In the Red Desert of Wyoming, Olson and Hansen (1977) compared the seasonal diets of cattle, sheep, and elk using fecal analysis techniques. The spring diets of elk and cattle in this study overlapped by 89%. The diets of elk and sheep overlapped the greatest (53%) during the winter.

2.5 Livestock and Elk: Potential for Competition

2.5.1 Livestock and Elk: Background on Competition

Competition, according to Miller (1967), can include two general elements, interference and exploitation. Interference refers to the differing abilities among competing species to limit access to a resource to themselves only. While exploitation refers to the differing abilities among competing species to exploit the resource. Mackie (1976) suggested that interference competition was not strongly developed among North American ungulates and exploitative competition was more common.

According to Nelson (1985), competition for food is the most typical form of exploitative competition among large herbivores. Ellis et al. (1976), Nelson (1985), and Sheehy (1987) suggested competition for forage resources involves a complex interaction of factors including: (1) physical and topographic influences, (2) animal distribution behavior patterns, (3) foraging behavior and capabilities, (4) timing of use, (5) number of each animal species, (6) intensity of use (7) forage availability, (8) intake and digestive passage rates of each species, and (9) dietary similarity.

Several authors have reported competition for a resource can occur without concurrent use (Cole 1958, Julander 1958, Stevens 1966, Mackie 1970, Mackie 1976, Mackie 1981, Nelson 1982). Elk may indirectly compete with cattle for spring forage because elk tend to utilize spring growth in foothill ranges first, before cattle are turned on, and then move to higher elevations as plant phenology progresses. Cattle grazing on these foothill ranges occurs later in the spring and then again in the fall, thus, removing forage which would normally have cured and been available for wintering elk.

2.5.2 Cattle and Elk: Abstract of Competition

The highest potential for competition between elk and cattle occurs on foothill rangelands which are used by cattle during the fall and used by elk during the winter. The diets of both ungulates overlap considerably while using these rangelands. However, the patterns of habitat use for cattle and elk are different in the foothill rangelands. Cattle tend to use the drainage bottoms and the lower slopes while elk are inclined to use the upper slopes and other areas of steep terrain. Consequently, the natural behavior of these ungulates typically keeps them spatially separated on these foothill rangelands, thus, minimizing the potential for competition. Notably, the use of cattle management techniques (salting, water developments, herding, and ect.) to gain a more even distribution of cattle on fall ranges may, in fact, increase the competition between elk and cattle if the cattle are moved into habitats previously only used by elk.

There is some indication elk may be inclined to avoid areas being grazed by cattle. However, on an area by area basis, the question of whether the presence of cattle in an area or their impact on the forage base of the area causes elk to avoid that area is debatable. Certain areas are not used by elk; despite the presence or absence of cattle, because these areas contain habitats elk instinctively avoid. However, research conducted in northeastern Oregon, within dual-use and big game-only pastures which contained similar amounts and types of habitat, seems to indicate the presence of cattle, even at light stocking rates, can influence elk distribution. Additionally, the type of cattle grazing management system used and the combination between the stocking rate used and the grazing system used can produce significantly ($P < 0.05$) different effects on elk distribution.

2.5.3 Cattle and Elk Competition: Season of Use

Skovlin et al. (1968) reported temporal differences in elk and cattle use on the Starkey Experimental Forest and Range in northeastern Oregon. Migrating elk used the area primarily in the spring and fall while cattle grazed there during the summer. Indirect competitive interactions may have occurred if spring elk use was heavy enough to decrease the summer forage availability for cattle or if summer cattle grazing limited the amount of forage available to elk in the fall.

Miller and Vavra (1982) studied the diets of cattle, elk and mule deer in the foothills of the Wallowa Mountains in northeastern Oregon. The summer diet of cattle and the winter diets of elk and mule deer all contained substantial amounts of Idaho fescue and bluebunch wheatgrass. Although the season of use on the open south slopes within the study area differed between cattle and big game, these areas presented considerable potential for dietary competition between cattle and big game.

Nelson (1982) described two examples of an "unilateral interaction" between cattle and big game: 1) where elk use of early spring foothill grasses in central Washington prior to cattle turn out reduced the amount of spring forage available to cattle; 2) where the cured bunchgrass forage was consumed by cattle during the fall on these foothill ranges resulting in a decrease of available forage for elk during the winter.

Miller and Krueger (1976) noted direct competition between cattle and big game (elk and mule deer) did not occur on their study area in the foothills of the Wallowa Mountains of Oregon. Differences in the season of use; cattle used the area from mid to late summer and big game in the spring and fall, probably minimized negative interspecific interactions (Miller and Krueger 1976).

In the Elkhorn Mountains of Montana, Stevens (1966) reported that although elk and cattle both used the high elevation, Engelmann/subalpine fir zone between July and September, the potential for direct competition between the two species was low due to differences in their diets during that time of year. Elk diets consisted of mostly forbs (72%) while cattle diets were primarily made up of grasses (71%).

Cattle summer diets and elk spring diets were more similar, with each containing a high percentage of grasses. Elk used the cattle summer range in mid to late spring before the cattle arrived. Given this situation, the potential for competition appeared high. However, interspecific competition was minimized by the substantial regrowth of grasses that occurred following spring elk use (Stevens 1966).

Stevens (1966) reported elk used the mid elevation, Douglas-fir zone within his Montana study area during the spring and fall while cattle used this vegetation zone during the summer and early fall. The potential for interspecific competition in the Douglas-fir zone was greatest in the fall when the grass content of elk diets increased, becoming more similar to summer and fall cattle diets. Open parks appeared to be the most likely sites for potential conflict. However, the difference in the timing of use of these areas apparently limited the amount of competition that occurred.

Steven (1966) noted elk used the lower elevation, fescue/wheatgrass zone as winter and spring range while cattle used this vegetation zone for summer and early fall range. Both elk and cattle diets contained high

percentages of grasses, 74% and 75%, respectively. Four grass species made up a substantial portion of both elk (48%) and cattle (68%) diets. Despite the high diet similarity of these two ungulates, competition did not appear to be serious. Differences in seasonal use patterns between the two ungulates seemed to limit interspecific competition. Summer cattle use in the fescue/wheatgrass zone occurred primarily on the lower slopes and in the drainage bottoms where water and shade were more available while winter and spring use by elk occurred on the ridges and south slopes which were more likely to be snow-free. Altering cattle distribution to increase the use on ridges and south slopes could increase the potential for conflict between elk and cattle in this vegetation zone.

Julander and Jeffery (1964) concluded the steepness of slopes and distance to water sharply limited the extent of cattle distribution on a rangeland. However, elk were only moderately limited by the steepness of slopes and distance to water and deer exhibited almost no response to these factors (Julander and Jeffery 1964). Consequently, on rangelands with moderate to high relief it is likely there would be large areas where cattle habitat and foraging use would only rarely overlap with that of elk and deer.

Working in the Missouri Breaks of Montana, Mackie (1970) reported habitat use of cattle and elk strongly overlapped during spring and fall but diverged during the summer. Elk and cattle chose similar habitat (sagebrush/wheatgrass type) during winter but remained spatially separated from each other. Winter diets were similar with western wheatgrass dominating the diets of both ungulates. By late May, elk and cattle diets had diverged. Late spring and summer elk diets were dominated by forbs while cattle diets were dominated by graminoids. During early fall, cattle and elk diets began to converge and by late fall were "almost identical". There was a potential for acute, direct competition between cattle and elk during the spring and fall. However, actual competition was minimized during the fall by differences in habitat use and during the spring by the tendency of elk to make heavy use of early season grasses and less use of western wheatgrass (*Agropyron smithii*) which was a preferred grass of cattle. The high mobility of the elk and their low densities in the study area also minimized interspecific competition.

Sheehy (1987) noticed cattle use of bunchgrass and ponderosa pine-bunchgrass communities within his study area in northeastern Oregon was highest in June, October, and November. Elk and mule deer use on the study area was heaviest between February and April with use peaking in March and April. Interspecific dietary overlap was highest between fall cattle diets and winter elk diets. These results suggest a potential for competition between cattle and elk on elk winter range. Spring elk diets and summer cattle diets overlapped the least indicating that spring elk grazing probably did not significantly effect the carrying capacity of cattle summer range.

2.5.4 Cattle and Elk Competition: Displacement of Elk

Skovlin et al. (1968) reported on ponderosa pine-bunchgrass summer range in northeastern Oregon, elk use in pastures where cattle were excluded was significantly higher than on pastures where both big game and cattle were allowed to graze. Mackie (1970) noted elk selectively utilized areas which had not been utilized by cattle during the same forage year. Steep terrain and forested areas were used in favor of open ridges and canyon bottoms where cattle normally grazed.

Working in the Elkhorn Mountains of Montana, Grover and Thompson (1986) reported the choice of spring feeding sites by elk was most strongly influenced by 4 of the 12 environmental factors they studied. The influences of previous cattle use, distance from the nearest visible road, bunchgrass density, and distance to cover explained 65% of the variability in feeding site locations.

In the Medicine Bow National Forest near Laramie, Wyoming, Ward et al. (1973) used radio-telemetry and direct observation to monitor the interaction between cattle and elk. Elk and cattle were concluded to be "socially compatible" based on numerous instances where cattle and elk were observed foraging in close proximity (25 to 100 m) of each other.

2.5.5 Cattle and Elk Competition: Stocking Rates

Skovlin et al. (1968) noted elk exhibited a negative response to increases in cattle stocking rates. Elk use of pastures moderately stocked with cattle (12 ha/A.U.) was significantly less than elk use on lightly stocked (16 ha/A.U.) pastures. However, there was no further significant decreases in elk use between heavily stocked (8 ha/A.U.) pastures and moderately stocked pastures.

2.5.6 Cattle and Elk Competition: Grazing Systems

Skovlin et al. (1968) reported elk use on summer range of the Blue Mountains of Oregon was not significantly different between pastures where the grazing system used was the only variable altered. However, comparison of elk use between pastures under different grazing systems and different stocking rates did indicate some highly significant responses. Under light cattle stocking, elk use was greatest on season-long ranges. Cattle tended to graze fewer plants under the season-long system than under the deferred-rotation system. It was suggested elk preferred ungrazed plants and the higher availability of ungrazed plants in lightly stocked pastures under the season-long grazing system was a reason for higher elk use in these pastures. Where stocking rates were heavy, elk selected for pastures grazed under a deferred-rotation system. Under heavy stocking, cattle on season-long pastures were inclined to repeatedly graze individual plants of certain species.

Repeated grazing did not occur as often on heavily stocked, deferred-rotation pastures. Higher forage availability was suggested as the reason for higher elk use on heavily stocked, deferred-rotation pastures.

Working in pastures of a rest-rotation cattle grazing management system in eastcentral Idaho, Yeo et al. (1993) observed elk tended to avoid pastures where cattle were grazing and apparently avoided pastures where cattle had grazed previously that season. Elk use in pastures which had been grazed by cattle tended to be more confined to forested habitats and terrain which was steeper and higher in elevation than was elk use in rested pastures.

2.5.7 Cattle and Elk Competition: Environment

Using fecal group counts to evaluate elk-cattle distribution in central Washington, Stark (1973) reported slope, canopy coverage, elk sedge cover, and distance from water all significantly influenced cattle and elk distribution. Slopes of less than 10% exhibited the highest potential for elk-cattle competition of any slope class. The potential for elk-cattle competition was less influenced by canopy closure than slope. Areas having full canopy closure exhibited the greatest potential for competition. Increasing elk sedge cover was significantly related to potential elk-cattle competition. Although cattle tended to remain closer to water than elk, the potential for competition between these ungulates was inversely correlated with distance to water.

2.5.8 Sheep and Elk: Abstract of Competition

The potential for competition between elk and sheep appears to be greatest on lands used concurrently by wintering elk and sheep. The diets of both ungulates contain a considerable amount of graminoids during the winter. However, throughout much of the West, lands used by ranchers to winter sheep are generally lower in elevation than those used by elk as winter range. Consequently, elk and sheep tend to remain spatially separate throughout most of the winter.

There is also a potential for elk and sheep to compete on high elevation rangelands, where the summer diets of elk and sheep both contain a dominance of forbs. However, the period of time when this competition is likely to occur is relatively short. Additionally, competition may be minimized by the tendency for elk to be more selective consumers of forbs than are sheep.

2.5.9 Sheep and Elk Competition: Season of Use

Olsen and Hansen (1977) noted the diets of elk and sheep in the Red Desert of Wyoming overlapped the greatest (53%) during winter when graminoids and shrubs were common in both diets. However, foraging elk appeared to concentrate on different species than did foraging sheep. Wheatgrasses formed the bulk of winter elk diets while saltbush (*Atriplex spp.*) was dominant in the winter sheep diets. The potential for competition between elk and sheep did not appear to be severe in this study.

On a southcentral Colorado winter range containing primarily shrub steppe and pinyon/juniper (*Pinus edulis/Juniperus spp.*) vegetation types, MacCracken and Hansen (1981) reported, based fecal analysis, the late spring diets of sheep and elk overlapped by 46%. Graminoids were common in the diets of both ungulates. However, the ranking of importance of each graminoid species was different between elk and sheep diets. Late spring sheep diets were dominated by western wheatgrass while elk diets contained similar amounts of sedges, fescues, western wheatgrass, and sagebrush during the late spring. MacCracken and Hansen (1981) concluded, despite the relatively high diet overlap between the two ungulates, elk and sheep did not seem to be competing for a limited forage resource during the late spring.

During summer on a high elevation rangeland in northeastern Oregon, Pickford and Reid (1943) noted elk and sheep tended to forage in the same habitats and their diets appeared to overlap extensively at the forage class level. However, the potential for severe competition between elk and sheep was apparently limited by differences in the diets at the forage species level. Although, the summer diets of both, elk and sheep contained primarily forbs, elk tended to consume forb species which were different than those consumed by sheep.

In the Elkhorn Mountains of Montana, Stevens (1966) suggested there was potential for severe competition between elk and sheep in the parks of the spruce/fir zone. However, the time period when this potential for conflict existed was quite short. Because this vegetation zone occurred at high elevation, the resulting delay in phenology of the forage species allowed elk to extend their spring, graminoid-dominated diet until mid June. Between mid June and the end of July, the diets of elk and sheep feeding in the parks of the spruce/fir zone contained predominantly forbs, 72% and 70% of the diet, respectively. However, after the end of July, the forb content in the elk diets decreased while the graminoid and browse content increased. Sheep diets in the spruce/fir zone continued to be dominated by forbs until late summer. Consequently, the potential for severe competition between elk and sheep only existed from mid June until the end of July.

2.5.10 Sheep and Elk Competition: Displacement of Elk

In Montana, Stevens (1966) reported elk used park habitats in the high elevation spruce/fir zone in the early summer but moved off to adjacent areas after sheep began using the parks. Shortly, after the sheep

arrived in the parks the elk habitually moved to higher elevation foraging areas, apparently following phenological cues from the forage species. In the Gravelly Mountains of Montana, Rouse (1957) also observed an apparent displacement of elk by sheep.

2.6 Livestock Impacts on Elk Forage

2.6.1 Abstract of Livestock Impacts on Elk Forage

Forage species in forested areas appear to be more sensitive to the use of different livestock grazing systems and stocking rates. Forage production by species in forested areas tends to be higher under deferred-rotation grazing systems than under season-long grazing systems. The species diversity of forest graminoids increases under light stocking rates but decreases under moderate and heavy stocking rates. Long-term livestock grazing can shift the species composition of a rangeland towards species less palatable to livestock and more grazing and trampling tolerant.

2.6.2 Livestock Impacts on Elk Forage

As part of the results of an 11 year study, Skovlin et al. (1976) reported the graminoids on grassland range in northeastern Oregon generally increased in production under light (4 ha/AUM), moderate (3 ha/AUM), and heavy (2 ha/AUM) stocking rates. However, the changes in grass production were not statistically significant ($P > 0.05$) for any of the stocking rate treatments. Forbs on grassland range generally increased under heavy stocking. Forbs of low palatability such as low gumweed (*Grindelia nana*) and rush pussytoes (*Antennaria luzuloides*) decreased under light cattle stocking but increased under heavy stocking. Palatable forbs such as balsamroot (*Balsamorhiza spp.*) and biscuitroot (*Lomatium spp.*) declined under heavy stocking.

On forested range dominated by a ponderosa pine overstory, differences in cattle stocking rates resulted in highly significant ($P < 0.01$) differences in graminoid production. Herbage production of elk sedge significantly declined by 1/6, 1/3, and 1/2 under light, moderate, and heavy stocking rates, respectively. Significant ($P < 0.05$) changes also occurred in the species composition on forested range under different stocking rates. The number of graminoid species increased by 10% under light stocking but decreased by 20% and 30% under moderate and heavy stocking, respectively. The response of forest forbs to stocking rate was variable and forest shrubs did not exhibit any definite responses to changes in stocking rate (Skovlin et al. 1976).

On grassland ranges, neither the individual species or the forage groups responded significantly to the differences in grazing management between the season-long system and the deferred rotation system. On forested ranges, the production of graminoids were significantly lower ($P < 0.05$) under the season-long system as compared to the deferred rotation system. Elk sedge production was much less ($P < 0.05$) under the season-long system. The more pronounced response to changes in grazing systems and stocking levels observed in the forest understory species as compared to the species in the grassland openings was apparently due to the added stress placed on the understory species by the forest crown closure (Skovlin et al. 1976).

Although limitations in experimental design prohibited statistical comparisons between dual-use ranges (cattle and big game) and big game-only ranges, Skovlin et al. (1976) reported on grasslands the production of some of the grass species appeared to increase at a higher rate on dual-use ranges under light and moderate cattle stocking than on big game-only ranges.

Rickard et al. (1975) reported spring cattle grazing within sagebrush-bunchgrass communities in southcentral Washington resulted in a pronounced reduction in the vigor of Cusick bluegrass (*Poa cusickii*), while bluebunch wheatgrass and Sandberg bluegrass were not acutely affected by spring grazing. However, several studies (Stoddart 1946, Blaisdel and Pechanec 1949, Wilson et. al. 1966, Mueggler 1972) have found spring defoliation of bluebunch wheatgrass can be detrimental and may have long-term effects (Mueggler 1975) on plant vigor.

In the Elkhorn Mountains of Montana, Stevens (1966) noted forage utilization by cattle and elk was not heavy on most of his study area, however, certain areas did receive concentrated use by both species. He suggested long-term, heavy use in these areas by cattle increased the forb content in the available forage. Elk were then attracted to these areas because of the higher forb availability. An explanation of why the cattle were attracted to these areas was not provided.

Bowns and Bagley (1986) compared a high elevation sheep summer range in southwestern Utah to an adjacent reference area that had been only lightly grazed by cattle and horses and was in near potential condition. Grasses dominated the sheep summer range with a limited number of unpalatable forbs species also occurring. In the adjacent reference area 88% of the plant species were forbs and only 4% were grasses. The species diversity was much higher on the reference area which contained 33 plant species while the sheep range contained only 18 plant species. Herbage production on the reference area was 190% greater ($P < 0.05$) than on the sheep range. The production of desirable forage species in the reference area exceeded total plant production on the sheep summer range.

Studying vegetative differences inside and outside of big game/cattle and cattle exclosures in northwestern Wyoming, Jones (1965) categorized the grazing responses of 18 principal forage species: 1) Prairie junegrass and Hood phlox appeared to be decreasers on cattle range and elk range; 2) Idaho fescue and Richardson geranium (*Geranium richardsonii*) appeared to be decreasers on cattle range but remained static on elk range; 3) tapertip hawksbeard (*Crepis acuminata*) was a significant ($P < 0.05$) decreaser on elk range but was unchanged on cattle range; 4) gray rabbitbrush (*Chrysothamnus nauseosus*) was a significant decreaser

($P < 0.05$) and American vetch (*Vicia americana*) appeared to be a decreaser on elk range but these 2 species were not evaluated on cattle range; 5) rose pussytoes (*Antennaria rosea*) increased significantly ($P < 0.05$) and needleandthread grass (*Stipa comata*), baldhead sandwort (*Arenaria congesta*), and fleabane (*Erigeron spp.*) appeared to be increasers under elk grazing but all 4 species maintained their status on cattle range; 6) notably, only needleleaf sedge (*Carex eleocharis*) appeared to increase under cattle grazing while remaining static on elk range; and 7) fringed sagebrush (*Artemisia frigida*) appeared to be a decreaser on elk range but increased under cattle grazing (Jones 1965). These data were reported as a technical note publication and were based on a limited sample size. Consequently, caution should be taken when interpreting these results.

In his review of the impacts of riparian grazing, Skovlin (1984) found livestock and wildlife browsing can seriously impact riparian trees and shrubs (McKell et al. 1972, Glinski 1977) but, has less impact than on upland shrubs (Young and Payne 1948, Garrison 1953, Willard and McKell 1978). Heavy use can prevent successful regeneration in browse species (Glinski 1977, Behnke 1978, Crouch 1978). However, Vogler (1978) found light grazing can actually enhance the vigor of many riparian shrubs. Earlier studies report stimulative effects by light grazing on a variety of riparian species (Aldous 1952, Ellison 1960, Jamison 1964).

2.7 Impacts of Elk on Vegetation

Pickford and Reid (1943) concluded, due to the high degree of dietary overlap between sheep and elk on a degraded northeastern Oregon rangeland and the increasing elk population in the area at that time, even exclusion of sheep grazing would not allow the range to recover from its degraded state unless elk use was curtailed.

Edgerton (1987) reported, after 11 years of big game exclusion, plots within a clearcut grand fir community in northeast Oregon exhibited a 400% increase in shrub cover while the shrub cover remained relatively static in adjacent, unprotected areas which had been subjected to big game use only. Within these same protected plots grass cover did not change significantly but outside the enclosure grass cover increased by 400%.

Based on studies by Korfhage et al. (1980), Edgerton (1987), and ongoing experiments (Irwin et al. 1994), Irwin et al. (1994) suggested selective grazing by wild ungulates, especially elk, has altered the plant composition of the Blue Mountains of Oregon away from shrub dominance. The observed declines in calf production in the Blue Mountains could be a negative feedback response to big game-induced declines in the quality of summer range (Irwin et al. 1994).

In the Bob Marshall Wilderness Area of Montana, Gaffney (1941) described the impact elk had on certain winter range grass and browse species. Trampling and heavy grazing of new spring grass growth by elk was quite detrimental to stands of certain grass species. Previously vigorous stands of rough fescue were

described as having been grazed to "almost complete destruction" by elk. Damage to stands of Idaho fescue and bluebunch wheatgrass by grazing elk was also reported.

Elk use on willows varied greatly from area to area. Willows on some portions of the winter range received almost no use while willows in other areas suffered 75% mortality due to heavy browsing. In some cases, high willow mortality may have been caused by a combination of winter and summer browsing by elk. However, as evidenced by willow growth inside and outside of elk exclosures, once browsing was excluded willows tended to regain vigor rapidly (Gaffney 1941).

Juvenile quaking aspen in some portions of the study area suffered 50% mortality due to overbrowsing by elk. Mature quaking aspen on these sites had been browsed by elk up to 2.5-3.0 m in height. In one area, quaking aspen trees up to 18 cm in diameter were girdled and killed by elk feeding on the bark. Unlike willows, quaking aspen tended to be slower in regaining vigor once browsing elk were excluded (Gaffney 1941).

Black cottonwood (*Populus trichocarpa*) was less widely distributed on the study area than willows or quaking aspen. However, almost all the available juvenile black cottonwoods in the area under 2 meters in height were damaged by elk browsing. Most of the damaged juvenile black cottonwoods were deformed, taking on a hedged appearance, rather than being killed. The lower limbs of mature black cottonwoods that were within reach of elk were heavily browsed but, due to their height and thick bark, mature black cottonwoods were not severely damaged by elk. However, any mature black cottonwood that was felled by beaver was rapidly stripped of palatable browse (Gaffney 1941).

Rocky Mountain maple (*Acer glabrum*), western chokecherry (*Prunus virginiana demissa*), and serviceberry were common throughout the study area before overbrowsing of certain portions of the winter range took its toll. All 3 species were highly palatable and received similar amounts of heavy browsing. In this area of Montana, these 3 species rarely grow to a height that would put their terminal leaders out of reach of browsing elk. Consequently, these species were browsed by elk until their hedged structure prevented access to live stems, browse production was minimized, or the plants were killed (Gaffney 1941).

The level of browsing use on ponderosa pine, Douglas-fir, and lodgepole pine on the study area was similar, indicating a similar degree of preference. However, because lodgepole pine was often present in large, young stands and because the lower branches of mature lodgepole were often low enough to be available to elk, lodgepole pine provided the largest amount of elk browse of the 3 conifer species. Heavy elk use limited or severely damaged conifer reproduction in some portions of the study area (Gaffney 1941).

In Yellowstone National Park, prior to 1968, much of the vegetation on the northern winter range had been seriously damaged by an excessively large elk population which had formed in the late 1800s and early 1900s after elk hunting had been banned in the park. Recognizing the problem, National Park Service personnel, between 1910 and 1967, periodically harvested or live-trapped and translocated elk in an effort to reduce the number of elk in the park. However, by 1968, public outcry concerning the "slaughter of Yellowstone elk" forced the National Park Service to re-evaluate their elk population control policy.

Eventually, the concept of "natural regulation" of elk within Yellowstone National Park was adapted by the National Park Service (Kay 1990).

The principle hypothesis behind the natural regulation concept was "vegetation-ungulate equilibria appropriate to the park" could be reached without using human harvest to control ungulate numbers within the park (Houston 1982:2). Specific hypotheses about the natural regulation concept within the northern range of the park were as follows (Houston 1982):

- 1) Where an ungulate population is "resource-limited", intraspecific competition will function in a density-dependent manner to limit the population size (Houston 1982:67).
- 2) The northern range of the park functions as an ecologically complete habitat.
- 3) Large numbers of elk have wintered on the northern range of the park for 8 to 10,000 years.
- 4) Co-evolution has occurred between the large numbers of elk, the vegetation, and the other ungulates on the northern range and these three factors have been operating in equilibrium for thousands of years.
- 5) Any changes in the species composition of the vegetation on the northern range that have occurred since Yellowstone National Park was established (1872) are the result of fire suppression or climatic change and are not the result of grazing by large numbers of ungulates.

After critical examination and testing of the natural regulation concept for the northern Yellowstone elk herd (see Kay 1990) and a review of the literature dealing with ungulate impacts on vegetation in other areas of the West, Kay (1994) concluded: 1) riparian shrub and tree species can be extirpated by concentrations of native ungulates; 2) native ungulates alter the structure of woody riparian vegetation; 3) heavy use by native ungulates can alter the species composition of riparian communities; and 4) native ungulates can have severe negative effects on riparian vegetation in both, winter and summer ranges.

In 1968, as part of the natural regulation policy of the National Park Service, human control of the number of elk within Rocky Mountain National Park was eliminated and the elk population was allowed to increase toward ecological carrying capacity (Stevens 1980). Stevens (1980) reported how the vegetation of the park was affected by the increasing elk population. Three upland habitat types on the low elevation winter range were examined. Within the bitterbrush/mountain mahoe (*Purshia spp./Muhlenbergia montana*) type, the cover of the dominant plant species remained relatively stable under the influence of the growing elk population. Sagebrush cover in the sagebrush habitat type significantly ($P < 0.05$) decreased with increasing elk numbers. Elk use affected the grassland habitat type less than the other two low elevation upland habitat types. In general, the low elevation upland vegetation and the populations of elk and other native ungulates appeared to be approaching an equilibrium without intolerable range deterioration (Stevens 1980).

In the low elevation bottom or riparian areas, the willow habitat type exhibited a fairly consistent but nonsignificant ($P > 0.05$) decrease in willow cover following winter elk browsing. On optimal sites, willows appeared to be tolerant of elk browsing but willows on marginal sites were prevented from reproducing by

even moderate levels of elk use. Browsing of willows on marginal sites by elk was suggested to increase the rate of succession on these sites towards a grass/sedge meadow (Stevens 1980).

Within the low elevation aspen habitat type, the density of aspen trees remained statistically stable despite the influences of the growing elk population. However, on sites where aspen were seral species elk browsing may have functioned to accelerate succession as in willow. On sites where aspen were stable or climax species elk browsing may have substantially altered the direction of succession (Stevens 1980).

No significant changes occurred within the habitat types of the alpine tundra winter range or the subalpine summer range. However, the willow habitat types in both the alpine tundra winter range and subalpine summer range appeared to be the most susceptible habitat types to losses in cover in response to increasing elk use (Stevens 1980).

2.8 Impacts of Elk on Private Property

Vavra (1980) provided a table of the results of an Oregon Cattlemen's Association big game damage survey conducted on the landowners within 21 Oregon counties. In four northeastern Oregon counties; Wallowa, Umatilla, Baker, and Union, the annual cost of elk damage to livestock grazing lands was 421,998 dollars. He suggested an important big game damage cost to livestock owners occurred when spring big game use postponed the range readiness of spring livestock range delaying the turn-on date and increasing the hay feeding costs incurred by the livestock owner. Increased labor and material costs associated with big game damage to fences and physical structures was also important. Big game damage to grain crops within the 4 Oregon counties mentioned above totaled 129,832 dollars annually. Hay crop damage totalled 146,832 dollars annually in these 4 counties (Vavra 1980).

Lacey et al. (1993) surveyed landowner perceptions of big game impact on private lands in southwestern Montana. Based on survey data from 456 landowners, average total costs attributable to big game use of private lands was \$6,467 per landowner. Forage consumption by big game cost an average of \$5,616 per landowner. Economic returns received from big game use of private lands averaged only \$114 per landowner.

Carpenter (1989) discussed the liability incurred by Colorado Division of Wildlife as a result of big game damage to hay crops and storage, seeded range, and seasonally deferred livestock forage in private lands. Calculation of big game damage to private property is a complex issue in which such factors as: big game species, current and historical population sizes, animal unit equivalencies, diet overlap, duration and season of overlap, and dollar value of the property damaged must be taken into account.

Using economic data from 1983, Carter and Radtke (1986) compared the amount of revenue that could potentially have been generated in Baker County, Oregon by forage used in the production of cattle and elk. They reported each AUM of forage utilized by cattle could have produced \$13.71 of local personal

income. Each AUM of forage utilized by elk could have produced \$7.11 to \$10.67 of local personal income depending on the nutritional requirement assumption used.

On a state-wide basis, each AUM of forage utilized by cattle in Baker County could have produced \$17.52 of state-wide personal income in 1983. Each AUM of forage utilized by elk could have produced \$29.46 to \$44.20 of state-wide personal income (Carter and Radtke 1986).

It appeared the production of cattle was more lucrative than the production of elk for the Baker County economy and the reverse was apparently true for the state-wide economy. However, these results can easily be misinterpreted if certain factors are not considered. Those people who bore most of the costs of elk production were not the same people who received most of the benefits of elk production. Livestock operators and their supporting businesses in Baker County lost personal income due to big game damage while businesses throughout the state who provided goods and services to hunters received gains in income (Carter and Radtke 1986).

2.9 Livestock and Elk: Complementary Relationships

2.9.1 Livestock Forage: Enhanced by Elk Grazing

Stoddart et al. (1975) suggested winter elk grazing potentially can prevent wolfiness in forage species by removal of standing litter thus providing better forage availability for summer livestock and big game use. Elk use of shrub species during the winter may regulate or limit the encroachment of these species into grasslands used by livestock during the summer (Nelson 1982).

2.9.2 Elk Forage: Enhanced by Livestock Grazing

Urness (1990) cites several sources which indicated that attempting to increase winter big game forage by terminating summer livestock grazing was ineffective or actually reduced big game carrying capacity (U.S. Forest Service 1970, Salwasser 1976, Leckenby et al. 1982, Neal 1982). Urness (1990) reviewed several studies conducted on the Hardware Ranch in northern Utah, which reported cattle (Smith and Doell 1968), horse (Reiner and Urness 1982), and sheep (Jensen et al. 1972) grazing reduced the herbaceous competition allowing decadent shrubs which were important big game browse species to regain vigor.

Anderson and Scherzinger (1975) discussed a case history of the livestock grazing management and winter elk population on the Bridge Creek Wildlife Management Area in northeastern Oregon. Prior to its establishment in 1961, the land making up the Bridge Creek Wildlife Management Area (BCWMA), was grazed by cattle without a definite management plan. Livestock grazing was eliminated when the BCWMA was

established. The number of elk wintering on BCWMA initially increased from approximately 120 to 320 head following the elimination of livestock grazing. However, after 3 years, winter elk numbers began to decline. Anderson and Scherzinger (1975) suggested winter elk use declined because the availability of quality forage on the BCWMA began to steadily decrease just 2 years after the elimination of livestock grazing. Apparently, standing dead material began to accumulate in the ungrazed perennial bunchgrasses hence limiting the availability of palatable forage for wintering elk. To help alleviate the forage availability problem and its effect on elk use, a rest-rotational cattle grazing system was instituted under which the pastures grazed early in the season during the boot to seed formation phenological stages for 2 consecutive years and then rested for 1 year. Under this grazing system winter elk numbers increased to 1,190 (Anderson and Scherzinger 1975).

Anderson and Scherzinger (1975) speculated the large and rapid increase in wintering elk numbers was due not only to elk being attracted to the BCWMA because of the reduction of "wolf" plants as a result of cattle grazing but also because the forage quality of the bunchgrass plants was enhanced by late spring-early summer cattle grazing. Apparently, the winter range forage quality was increased if cattle were allowed to graze in the early season and then removed while there was still enough of the growing season left that the plants could regrow a substantial amount before temperature and soil moisture conditions forced the plants into dormancy. Anderson and Scherzinger (1975) stressed three grazing management requirements were critical for successfully manipulating quality and availability of winter elk forage on bunchgrass-dominated winter ranges similar to the BCWMA. First, grazing of the bunchgrass plants must be closely monitored since defoliation of the plants occurs between the boot and seed formation stages of phenology. Second, climatic and soil moisture conditions must also be closely monitored so grazing is halted at a point when enough growing season remains the plants can put on sufficient regrowth to meet the forage quantity needs of wintering elk. Finally, treated pastures should be rested every third or fourth year to prevent substantial reductions in forage plant vigor.

On a bunchgrass-dominated elk winter range in southeastern Washington, Skovlin et al. (1983) used pellet group count methodology to evaluate winter elk use of plots grazed by cattle from mid April to early June. The spring cattle grazing treatment had no significant effect on winter elk use when averaged over the 3 winters of the study. However, elk use was significantly ($P < 0.01$) less on the grazed plots as compared to the ungrazed plots during the second winter of the study.

In the Elkhorn Mountains of Montana, Dragt and Havstad (1987) reported summer cattle grazing under a deferred-rotation grazing management system was not detrimental to the quality of winter elk forage. Neither bluebunch wheatgrass or rough fescue exhibited a significant ($P < 0.05$) winter forage quality response relative to the phenological stage in which it was grazed during the summer. Although the overall winter forage quality of Idaho fescue was not significantly altered by summer cattle grazing, there were significant ($P < 0.05$) decreases in neutral detergent fiber (NDF) and acid detergent fiber (ADF) percentages in plants that were grazed during the seed shatter stage as compared to plants that were grazed during the boot and vegetative stage of phenology. It was concluded the quantity rather than the quality of winter elk forage was more critically related to summer cattle grazing management (Dragt and Havstad 1987).

During the spring, Grover and Thompson (1986) reported elk in the Elkhorn Mountains of Montana preferred to feed in areas previously grazed by cattle. These findings appear to support Willms and McLean (1978) who suggested cattle grazing removed the less palatable old growth from spring forage plants making the succulent new growth more available to wild ungulates. Grover and Thompson (1986) stressed manipulation of cattle grazing to improve the quality of spring elk forage should take into account the effect this manipulation would have on the forage supply of wintering elk.

Jourdonnais and Bedunah (1990) used fall cattle grazing to enhance the quality and availability of winter elk forage on a rough fescue dominated winter range in the Sun River Wildlife Management Area, Montana. Winter elk use on rough fescue and Idaho fescue in the cattle grazed plots was higher ($P < 0.10$) than on ungrazed plots. Bluebunch wheatgrass, especially plants with reproductive culms present, received only slight utilization by wintering elk.

Laycock (1967) studied the differences in sagebrush and vegetative response between spring and fall sheep grazing on the Upper Snake River Plains of Idaho. Spring grazing caused further degeneration on range already in poor condition. On range initially in good condition, spring grazing caused three-tip sagebrush (*Artemisia tripartita*) cover to increase significantly ($P < 0.01$) and the production of understory plants to decrease significantly ($P < 0.01$). Spring grazing also tended to increase the percentage of unpalatable and undesirable species in herbaceous species composition. On degraded range, fall grazing appeared to reduce the sagebrush cover and increase the total production of the remaining, desirable grasses and forbs. On good condition range, under 39 years of fall grazing, the range condition was maintained. Notably, total production of grasses and forbs increased significantly ($P < 0.05$) under long-term fall grazing as compared to the production within an adjacent exclosure which contained range in good condition at the time the exclosure was built. He advocated fall grazing could be used to improve and maintain the condition of similar ranges for the benefit of livestock production. These results also may have application for improving the condition of degraded elk winter range.

2.10 Bluebunch Wheatgrass: Effects of Defoliation

2.10.1 Bluebunch Wheatgrass: Effects on Vigor

The principal effect of grazing on grasses is the removal of photosynthetic tissue and the consequent reduction of the photosynthetic capacity of the plant (Briske 1991). The response of perennial grasses to grazing is related to the intensity, duration, and phenological timing of defoliation. Grasses such as Kentucky bluegrass, buffalo grass (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*) and side-oats grama (*Bouteloua curtipendula*), which probably coevolved with large herbivores, tolerate intense grazing by not elevating their apical meristems within reach of grazing animals (Branson 1953). In these grasses, regrowth

after grazing occurs by continued expansion and elongation of existing tillers. Caespitose grasses such as bluebunch wheatgrass elevate their apical meristems above the soil surface and readily accessible to herbivores (Branson 1953, Caldwell 1981). Regrowth of photosynthetic tissue, in plants where grazing has removed the apical meristems, must occur by tiller initiation from axial buds on parent tillers (Briske 1991) requiring much more energy than regrowth by continued expansion and elongation.

Total nonstructural carbohydrates stored in the roots and root crown are the main energy reserves for growth and development of perennial grasses (Cook 1966a, White 1973). These plants draw upon their reserves to initiate new growth in the spring and fall or to replace photosynthetic tissue following defoliation during the growing season (Menke 1973).

A mass flow mechanism seems to be involved in translocation of total nonstructural carbohydrates between storage sinks in the roots and root crown and above-ground portions of the plant (Fensom 1957, Spanner 1958, Biddulph 1969, MacRobbie 1971). Total nonstructural carbohydrates are only available to grazing animals when translocated to the top-growth of the plant. Plants undergoing rapid growth and development translocate much of their stored energy to sites of active growth.

Cook (1966a) observed the lowest point of total nonstructural carbohydrate storage in perennial grasses occurs during the early vegetation growth stage. McIlvanie (1942) reported stored energy in the roots reached its lowest level when leaves attained 9-15 cm in length. A deficit in the root energy reserves of bluebunch wheatgrass occurred until the plants had completed 45% of their seasonal growth. Root energy reserves were depleted to 28% of the initial level during vegetative growth before enough photosynthate was produced to balance the deficit (McIlvanie 1942).

Similarly, Daer and Willard (1981) reported total nonstructural carbohydrate storage in the roots and root crown coincided with the completion of 29% of the vegetative growth and 13 cm in average leaf length. Root and root crown energy storage reached its highest point during the inflorescence emergence stage when 67% of vegetative growth was completed and the average leaf length was 30 cm.

Bluebunch wheatgrass appears to be most susceptible to reductions in vigor during the late spring (Stoddart 1946, Blaisdell and Pechanec 1949, Wilson et al. 1966, Mueggler 1975). Working in northern Utah, Stoddart (1946) evaluated the vigor and chemical composition responses of bluebunch wheatgrass to 2.5 cm or 5 cm clipping at weekly or biweekly intervals during spring, fall or spring/fall. Stoddart (1946:22) summarized his findings as follows:

"...damage to the grass from herbage removal was inversely proportionate to herbage exposed to sunlight during the warm season as attained by (a) less close clipping, (b) clipping early enough to allow regrowth prior to summer drought, or (c) clipping late enough to allow food storage before herbage was removed."

During early spring the date of the last clipping was a crucial factor affecting herbage yield and plant mortalities. Treatments where clipping ceased earlier in the spring were less detrimental. In late spring and summer, the date of the initial clipping was the most influential factor measured. Treatments started later in the season were less damaging (Stoddart 1946).

McLean and Wikeem (1985) clipped bluebunch wheatgrass at weekly intervals under spring only, spring/fall, or fall only treatments. Plants clipped from early spring until mid summer suffered the highest mean mortality (92%) and had the lowest mean leaf height (11.5 cm), tiller number (21.2/plant), and dry matter yield (0.61 g/plant) (i.e., pooled means for two locations over three years).

Blaisdell and Pechanec (1949) clipped bluebunch wheatgrass plants in Idaho to ground level during spring, summer or fall. Plants clipped in early to mid June had the lowest herbage yields and flower stock production compared to plants clipped earlier or late in the season.

In southeastern Washington, Wilson et. al. (1966) observed bluebunch wheatgrass was most prone to injury from grazing during the boot stage. Three consecutive years of ground-level defoliation during the boot stage could result in high mortality of bluebunch wheatgrass plants. Yield could be reduced as much as 70% when compared to ungrazed plants. After three consecutive years of 10 cm clipping, the yield of bluebunch wheatgrass declined substantially. Ground level clipping resulted in little additional decrease in yield compared to 10 cm clipping.

In southwestern Montana, Mueggler (1975) applied competition/clipping treatments to bluebunch wheatgrass. Even where the competition from neighboring plants was reduced by ground level clipping, bluebunch wheatgrass plants clipped a stubble height of 28% of the total plant height just prior to inflorescence emergence (i.e., late boot stage) required more than five years to recover vigor to a level similar to control plants (i.e., unclipped plants under full competition).

2.10.2 Bluebunch Wheatgrass: Effects on Forage Quality

The forage quality of range plants follow an annual pattern where carbohydrates, crude protein, vitamins and water occur in the most elevated levels in spring vegetative growth (Heady 1975). The nutritional quality of forage plants tends to decline as phenology progresses (Skovlin 1967, Holechek et al. 1981). Anderson and Scherzinger (1975) hypothesized prescribed livestock grazing could be used to enhance the quality of bunchgrass-dominated elk winter ranges. Grazing of bluebunch wheatgrass during the boot-to-seed stages could delay plant phenology enough that the regrowth produced following defoliation does not progress beyond the early seed stalk stage before high temperatures and low soil moisture induced summer quiescence. Consequently, spring grazed plants would cure at a younger and more nutritious phenological stage than would ungrazed plants.

In southern British Columbia, Pitt (1986) sampled the response in phenological development, acid detergent fiber, crude protein, calcium, and phosphorus of bluebunch wheatgrass plants clipped to a 15 cm stubble height in five different treatments corresponding to four different phenological stages: 1) unclipped control, 2) boot stage, 3) inflorescence emergence, 4) flowering, and 5) seed formation. These treatments were repeated on the same plants for two years. During each year, forage samples were collected from the treated

plants during nine phenological stages: 1) vegetative, 2) boot, 3) inflorescence emergence, 4) flowering, 5) seed formation, 6) ripe seed, 7) seed shatter, 8) stem cured, and 9) weathered.

After two years of treatment, all of the clipping treatments delayed plant phenology, decreased acid detergent fiber, and increased crude protein and mineral content compared to the control. Plants clipped in the boot stage flowered 16 days later than the control while plants clipped during seed formation flowered as much as 142 days after the control. Acid detergent fiber content of forage samples collected during the stem cured stage in the second year of the study were 49.8%, 43.3%, 38.1%, 42.4%, and 38.9% for the control, boot, inflorescence emergence, flowering, and seed formation treatments, respectively. Crude protein content during the stem cured stage was 4.6%, 7.6%, 8.7%, 9.6%, and 12.3% for the control, boot, inflorescence emergence, flowering, and seed formation treatments, respectively. The calcium content in stem cured samples was 0.22%, 0.66%, 0.67%, 0.42%, and 0.40% for the control, boot, inflorescence emergence, flowering, and seed formation treatments, respectively. Phosphorus contents of 0.07%, 0.13%, 0.14%, 0.18%, and 0.25% were observed in samples collected during the stem cured stage for the control, boot, inflorescence emergence, flowering, and seed formation treatments, respectively (Pitt 1986). Pitt (1986) concluded prescribed livestock grazing could be used to enhance the nutritional quality of fall forage on bluebunch wheatgrass dominated rangelands with environmental conditions similar to southern British Columbia.

Dragt and Havstad (1987) examined the effect of summer cattle grazing at eight different phenological stages on the winter forage quality of bluebunch wheatgrass, rough fescue, and Idaho fescue in the Elkhorn Mountains, Montana. Individual plants from these three species were monitored biweekly for utilization during the summer cattle grazing season. During the following March, forage samples were collected from these individual plants and classified based on the utilization history of each plant.

The crude protein, ash, acid detergent fiber, neutral detergent fiber, and acid detergent lignin of bluebunch wheatgrass and rough fescue plants grazed by cattle during the summer (i.e., irrespective of the phenological stage grazed) were not significantly different ($P > 0.05$) than ungrazed plants (Dragt and Havstad 1987).

In the Blue Mountains of northeastern Oregon, Bryant (1993) sampled the winter forage quality of bluebunch wheatgrass plants clipped to 2.5 cm or 7.6 cm just prior to the boot stage or to 7.6 cm after plant maturity in the fall. Spring clipping increased the crude protein and *in vitro* dry matter digestibility while decreasing acid detergent fiber and acid detergent lignin compared to the unclipped control. Fall clipping produced the largest forage quality response of any of the clipping treatments. However, late summer/fall precipitation only occurred in amounts adequate to stimulate fall growth during one year of the study.

Based on elk nutritional requirement data compiled by Nelson and Leege (1982), Bryant (1993) concluded, although the spring clipping treatments enhanced the winter forage quality of bluebunch wheatgrass compared to the control, the forage quality from the spring clipping treatments still was not adequate to meet the maintenance requirements of winter elk. The forage quality of the fall treatment samples exceeded the winter maintenance requirements for elk. However, the occurrence of fall precipitation was highly

unpredictable in the Blue Mountains, Oregon. Consequently, use of fall livestock grazing to enhance the winter forage quality of bluebunch wheatgrass may be effective during years of adequate fall precipitation but may critically reduce the quantity of forage available to wintering elk during dry falls (Bryant 1993).

Working at the same study sites as Bryant (1993), Westenskow-Wall et al. (1994) evaluated the calcium, phosphorus, *in vitro* dry matter digestibility, and dry matter yield of bluebunch wheatgrass following spring and fall clipping treatments. The spring clipping treatment consisted of clipping bluebunch wheatgrass plants to a 7.6 cm stubble height just prior to the boot phenological stage. Fall clipped plants were clipped to a 7.6 cm stubble height in September prior to fall rains. Forage samples from the treated plants were collected during the following November and April. Spring clipping did not produce any significant differences ($P>0.05$) in percent calcium, percent phosphorus, or dry matter yield compared to the unclipped control. *In vitro* dry matter digestibility of spring clipped forage was enhanced only during one year of the study. The fall clipping treatment improved the *in vitro* dry matter digestibility and phosphorus content of the forage but greatly decreased the dry matter yield. The calcium and phosphorus contents of fall clipped forage were sufficient to fulfil the nutritional requirements of wintering elk. However, as concluded by Bryant (1993), fall grazing may cause a critical reduction in winter forage for elk if fall precipitation does not occur in sufficient amounts to simulate fall regrowth.

2.11 Idaho Fescue: Effects of Defoliation

2.11.1 Idaho Fescue: Effects on Vigor

In southwestern Montana, Mueggler (1975) clipped bluebunch wheatgrass and Idaho fescue plants under varying levels of competition from neighboring plants. Idaho fescue appeared to be less sensitive to clipping than bluebunch wheatgrass and recovered vigor more quickly as well. Idaho fescue plants receiving extreme clipping under partial competition or heavy clipping under full competition required three years of protection to regain normal vigor compared to the 6 years projected for bluebunch wheatgrass.

2.11.2 Idaho Fescue: Effects on Forage Quality

To my knowledge only one study has specifically examined the effect of grazing or clipping on the winter forage quality of Idaho fescue. Dragt and Havstad (1987) reported the neutral detergent fiber and acid detergent fiber were reduced ($P<0.05$) in Idaho fescue plants grazed by cattle during the seed shatter stage compared to ungrazed plants

2.12 Elk Sedge: Effects of Defoliation

2.12.1 Elk Sedge: Effects on Vigor

At Starkey Experimental Forest and Range in the Blue Mountains of northeastern Oregon, Driscoll (1957) examined the effects of clipping date and intensity on the herbage and seed stalk production of elk sedge. Because of experimental design problems, the effect of clipping date could not be statistically evaluated. However, the effect of the first clipping date, which corresponded to late dough stage of elk sedge and inflorescence emergence stage of local bluebunch wheatgrass plants, appeared to have a more detrimental effect on the vigor of elk sedge than did three later clipping dates spaced at 30 day intervals. No significant differences ($P < 0.05$) in herbage production were detected between plants receiving 20%, 40%, or 60% herbage removal treatments. However, some nonsignificant trends in herbage production versus clipping intensity were noticed. Clipping at 40% and 60% appeared to be more detrimental to elk sedge herbage production than did 20% herbage removal. Seed stalk production was significantly greater ($P < 0.05$) in the 20% harvesting intensity treatment than in the 40% or 60% treatments.

2.12.2 Elk Sedge: Effects on Forage Quality

To my knowledge no study has evaluated the effect of grazing or clipping on the winter forage quality of elk sedge.

2.13 Elk Nutritional Requirements

2.13.1 Elk Nutritional Requirements: Energy

The nutritional requirements of elk have not been as extensively researched as in other cervids (eg. white-tailed deer [*Odocoileus virginianus*] and red deer [*Cervus elaphus scoticus*]). Documented knowledge of the energy requirements of free-ranging elk is essentially unavailable. Many studies have examined the diet composition (Mackie 1970, Kufeld 1973, Skovlin and Vavra 1979, Korfhage et al. 1980, Hobbs et al. 1981, MacCracken and Hansen 1981, Hobbs et al. 1983, Sheehy 1987) and diet quality of free-ranging elk (Ward 1971, Nowlin 1974, McArthur 1977, McReynolds 1977, Hobbs et al. 1981, Weber 1981, Rowland et al. 1983, Brooks et al. 1984, Bryant 1993, Westenskow-Wall et al. 1994). However, the influence of diet on the nutritional status, body condition and performance of free-ranging elk has received only limited research

(Nelson and Leege 1982, Swift 1983). In an attempt to bridge this gap of information, researchers have used our knowledge of ruminant digestive physiology and metabolism, daily activity patterns of wild elk, and nutritional requirements of ruminant livestock to predict the energy and nitrogen requirements of free-ranging elk (Hobbs et al. 1982, Nelson and Leege 1982, Swift 1983).

The nutritional requirements of beef cattle and red deer have been extensively researched and may provide valuable information on the nutritional requirements of elk. The National Research Council (1984) reported adult beef cattle require 138 kcal metabolizable energy (ME)/kg^{0.75} body weight to meet daily maintenance costs. Kay and Staines (1981) and Fennessy et al. (1981) noted similar maintenance energy requirements (136 kcal ME/kg^{0.75} body weight) for red deer adults.

Using the interspecific average standard metabolic rate (SMR) of 70 kcal/kg^{0.75} body weight/day (Kleiber 1961), energy expenditure rate data from livestock (Moen 1973), and daily activity budget data from free-ranging elk (Craighead et al. 1973), Nelson and Leege (1982) calculated seasonal energy expenditures of cow elk for SMR and activity. Based on these calculations, a cow elk would require 100 kcal ME/kg^{0.75} body weight/day to meet maintenance energy costs (i.e., SMR and activity) during winter. Assuming the cow elk weighed 236 kg, her daily maintenance energy requirement would be 6,035 kcal ME.

In Colorado, Hobbs et al. (1982) used activity energetics data from Gates and Hudson (1978) and activity budget data collected by telemetry to calculate the energy requirements for maintenance of a free-ranging elk. During winter, a 200 kg elk would require 172.7 kcal ME/kg^{0.75} body weight/day for maintenance or 9,185 kcal ME/day. Using data from Hobbs et al. (1982), a 236 kg cow would require 10,399 kcal ME/day for winter maintenance which is substantially higher than the results reported by Nelson and Leege (1982). Calculated energy costs for specific activities varied widely between Nelson and Leege (1982) and Hobbs et al. (1982) which would likely explain some of the difference in their results.

Using indirect calorimetry on expired gases captured via a tracheal cannulae, Wickstrom et al. (1984) observed a 155 kg female elk feeding on grasses and/or forbs expended 1.55 kcal/kg body weight/hr. The energy cost for eating (i.e., apart from costs for standing or posture maintenance) was 0.32 kcal/kg body weight/hr. Pauls et al. (1981) reported the energy cost of eating above costs for standing was 0.79 kcal/kg^{0.75} body weight/hr for grazing elk.

Gates and Hudson (1978) used a respiratory mask to measure the energy costs of standing, lying and walking for 2 female elk, Elk 1 weighing 153 kg and Elk 2 weighing 161 kg. The average energy expenditure for standing for these two elk was 1.29 kcal/kg body weight/hr. The energy cost of lying was 1.03 kcal/kg body weight/hr. Ruminating while lying may increase energy costs by 2% over lying with head up (Pauls et al. 1981). Average expenditures for walking at 2 km/hr, 3 km/hr, and 4 km/hr over the costs of standing were 1.09 kcal/kg body weight/hr, 1.38 kcal/kg body weight/hr, and 1.85 kcal/kg body weight/hr, respectively (Gates and Hudson 1978).

Additional energy requirements for gestation probably do not become significant until approximately 80 days of gestation (i.e., early December for mid September conceptions) and likely do not become a serious

energy cost until 170 days gestation (i.e., mid March) (Moen 1973, Nelson and Leege 1982). Energy costs for gestation and lactation become increasingly important between early spring and mid summer.

Winter temperatures in the Blue Mountains of northeastern Oregon generally do not remain below the lower effective critical temperature (LCT) for adult elk (i.e., the lower limit of the thermal neutral zone) for extended periods of time. Consequently, wintering elk probably do not require additional energy intake for maintenance of homeothermy except during times of extremely cold weather (i.e., less than -20°C) or when cold temperatures are coupled with high winds.

Based on data from red deer (Brockway and Maloiy 1967), Nelson and Leege (1982:330) estimated the LCT for a 236 kg elk was -16°C but this figure may be "much in error" due the amount of extrapolation involved in the calculations. Parker and Robbins (1985) reported the LCT for a 91.7 kg elk was -20°C while standing with winter pelage. Energy expended in metabolic heat production while standing was $76.6 \text{ kcal/kg}^{0.75}/\text{day}$ (Parker and Robbins 1985). During winter and spring, Gates and Hudson (1979) noted the LCT for a 125 kg lying or standing elk was -10°C . Daily metabolic heat production for the lying elk was $12.0 \text{ kcal/kg}^{0.75}$ and $158 \text{ kcal/kg}^{0.75}$ for the standing elk.

2.13.2 Elk Nutritional Requirements: Crude Protein

Protein is important for cellular function, digestion, growth, reproduction, and lactation. Protein deficiency can critical affect these processes. Unlike monogastrics, the nitrogen content rather than protein quality is an important factor in ruminant diets. Proteins and nonprotein nitrogen sources ingested by ruminants are disassembled and restructured by the rumen microorganisms to satisfy the protein requirements of the rumen microorganisms. Since dietary nitrogen is essential to microbial function, nitrogen deficiencies can reduce the digestion of carbohydrates and fats (Nelson and Leege 1982, Van Soest 1982). The nitrogen content of feeds is commonly expressed as crude protein ($6.25 \times$ percent nitrogen).

Similar to energy requirements, data on the nitrogen or crude protein requirements for free-ranging elk are quite limited. Hobbs et al. (1982) calculated the total maintenance nitrogen requirements for free-ranging elk based on a metabolic fecal nitrogen excretion rate of 5.6 g N/kg dry matter intake (Mould and Robbins 1981), endogenous urinary nitrogen losses of $0.16 \text{ g N/day/kg}^{0.75}$ body weight (Mould and Robbins 1981) and voluntary dry matter intake rate of 2.5% of body weight/day (Hungerford 1948, Geis 1950, Hobbs 1979). The total maintenance nitrogen requirements for a 200 kg elk would be 36.0 g N/day . Based on data from Hobbs et al. (1982), a free-ranging 200 kg elk would require a diet containing 4.5% crude protein to meet its nitrogen requirements.

Nelson and Leege (1982) used elk feeding trial data from Thorne et al. (1976), livestock protein digestibility coefficients for the feeds used in the feeding trials (McDonald et al. 1973), and equations from Moen (1973) to calculate the protein requirements for maintenance of gestating cow elk. A 260 kg cow, fed a

native hay and grain concentrate ration and producing an 18.4 kg fetus at term, would require an estimated 163.3 g of digestible protein/day for maintenance. Nelson and Leege (1982) estimated this 260 kg cow would require a diet containing 5.5% crude protein for maintenance under confinement conditions.

Chapter 3

Effect of Late Spring Defoliation on the Forage
Quality of Bluebunch Wheatgrass for Wintering Elk

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3. EFFECT OF LATE SPRING DEFOLIATION ON THE FORAGE QUALITY OF BLUEBUNCH WHEATGRASS FOR WINTERING ELK

3.1 Abstract

Bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) was hand clipped to a 7.6 cm stubble height in early June under one of three different phenological stage/intensity level combinations: 1) mid boot/whole plant clipped, 2) mid boot/one-half of the plant's basal area clipped, and 3) inflorescence emergence/whole plant clipped. All three combinations resulted in significantly higher percent crude protein and percent *in vitro* dry matter digestibility in forage samples collected in early November compared to samples from unclipped control plants. Dry matter yield in unclipped control plants was significantly greater than in plants receiving clipping treatments. Although, the increases in forage quality resulting from the clipping treatments were relatively small, these increases may be important to the viability of wintering elk on a low plane of nutrition.

3.2 Introduction

Many Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) in northeastern Oregon, as in other western states, winter on what were historically transitional or spring-fall rangelands (Skovlin and Vavra 1979, Sheehy 1987, Sheehy and Vavra 1995, Sheehy and Vavra 1996). Suburban expansion, agricultural development, and other forms of human disturbance have made much of the traditional elk winter range on the valley floors and lower elevation foothills unavailable to wintering elk. Consequently, many elk in northeastern Oregon are occupying spatially incomplete winter habitat (Cole 1971, Vavra 1992, Sheehy and Vavra 1995).

Transitional rangelands typically have shallow, droughty soils, relatively short growing seasons, and much lower forage production than rangelands on the valley floors. Transitional rangelands generally have deeper and more persistent snow accumulations which not only reduce the availability of the already limited forage supply but, also increase the energy costs to feeding or traveling elk (Parker et al. 1984, Fancy and White 1985).

The grassland vegetation on transitional rangelands in northeastern Oregon is dominated by native perennial grasses such as bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) and Idaho fescue (*Festuca idahoensis* Elmer). Previous researchers have suggested spring livestock grazing may be useful to improve the forage quality of perennial grasses, especially bluebunch wheatgrass, on elk winter ranges (Anderson and Scherzinger 1975). Numerous studies have examined the effects of defoliation on the forage production and chemical composition of perennial grasses (Aldous 1930, McIlvanie 1942, Stoddart 1946, Blaisdell et al. 1952, Hyder and Sneva 1963a, Hormay 1970, Hyder 1971, Jensen et al. 1972, Bedell

1973, Demarchi 1973, Willm et al. 1980, Daer and Willard 1981, Pitt 1986, Bryant 1993, Westenskow-Wall et al. 1994). Results from these studies suggest the forage quality response of perennial grasses to defoliation is strongly related to the phenological timing of defoliation, amount of the photosynthetic and meristematic tissue removed, number of intact tillers remaining, the number of defoliations occurring during the growing season, and the length of growing season remaining after the final defoliation.

In northeastern Oregon, Westenskow-Wall et al. (1994) noted the forage quality of the regrowth from bluebunch wheatgrass clipped just prior to the boot stage was similar to unclipped plants. Apparently, enough growing season remained after the pre boot clipping that the regrowth in the clipped plants was able to phenologically mature similarly to unclipped plants producing no real benefit to the nutritional status of winter grazers.

Pitt (1986) reported bluebunch wheatgrass plants clipped after the boot stage were of higher forage quality than unclipped plants. However, defoliation between the boot stage and late summer quiescence may be seriously detrimental to plant vigor (Trlica and Cook 1972). Fall clipping can result in production of highly nutritious regrowth but may also substantially reduce forage quantity, especially during years of little or no fall precipitation, and this may critically affect the nutritional status of wintering elk (Bryant 1993).

Comparison of total nonstructural carbohydrate (TNC) storage in bluebunch wheatgrass to phenological development (McIlvanie 1942, Daer and Willard 1981) suggests if bluebunch wheatgrass were defoliated during the mid boot stage, when root and root crown carbohydrate reserves had been photosynthetically restored to more than 50% of the seasonal maximum (Daer and Willard 1981), then the plants would have enough reserves and enough growing season remaining to survive, replace photosynthetic tissue and TNC reserves, and produce forage of higher quality than undefoliated plants.

Our objective was to examine the effect of late spring clipping on the crude protein, *in vitro* dry matter digestibility, and dry matter yield in the regrowth of bluebunch wheatgrass when measured during early November. We tested the hypothesis that whole plant clipping during mid boot phenological stage represented the optimal combination of phenological timing and intensity of defoliation to produce regrowth of high forage quality and ample forage quantity for wintering elk.

3.3 Study Areas

The study was conducted in 1993 and 1994 at two study sites; Winter Ridge and McCarty Spring, located in the Blue Mountains of northeastern Oregon approximately 35 and 48 km southwest of La Grande, Oregon, respectively. Both study sites were located on USDA Forest Service land managed as big game winter range. The following criteria were used in selection of the study sites: 1) location on an open ridgetop, 2) southerly to westerly aspect, 3) grassland vegetation type dominated by bluebunch wheatgrass, 4) sufficient density of vigorous bluebunch wheatgrass plants for statistically rigorous sampling, 5) location on public land, and 6) representative of winter range frequently used by elk from November to April.

As part of two previous studies (see Bryant 1993 and Westenskow-Wall et al. 1994), an 0.5 ha livestock enclosure had been constructed at each study site in 1986. The McCarty Spring enclosure was located on a gently sloping (0 to 5%) westerly aspect at 1,274 m in elevation. The elevation of the Winter Ridge enclosure was 1,366 m with a gently sloping (0 to 7%) south-southwesterly aspect.

The vegetation at both study sites was classified as bunchgrass on shallow soil, gentle slopes, GB-49-11 (Hall 1973). The dominant perennial grasses were bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass (*Poa secunda* Presl.), prairie junegrass (*Koeleria cristata* Pers.), and Kentucky bluegrass (*P. pratensis* L.). Annual grasses such as cheatgrass (*Bromus tectorum* L.) and soft brome (*B. mollis* L.) dominated ecologically disturbed sites. Western yarrow (*Achillea millefolium* L.) was the most common perennial forb. No shrub species were recorded at either site.

The soils on both sites were shallow, extremely stony to very cobbly, loams and silt-loams of the Anatone-Bocker complex (Dysterhuis and High 1985, Bryant 1993). The shallowness and droughtiness of these soils were likely the most limiting factors to vegetative production at these sites (Dysterhuis and High 1985).

The climate was continental with low precipitation, warm to hot summers and cold, dry winters. Most of the precipitation occurred as winter snow and spring rain. The amount and timing of late summer and fall rain was unpredictable but, could occur in sufficient amounts to promote substantial regrowth in perennial grasses. Annual precipitation totals for 1993 and 1994 at Starkey Experimental Forest and Range, less than 15 km away from both study sites, were 59.7 cm and 50.7 cm, respectively. The ten year average (1986 to 1995) for annual precipitation at Starkey Experimental Forest and Range was 54.8 cm (Unpub. data, on file at Forestry and Range Sciences Laboratory, La Grande, OR).

3.4 Methods

3.4.1 Experimental Design

A completely randomized experimental design was used. At each study site, the area within the livestock enclosure (excluding a 10 m wide fence buffer zone) was divided into 10 m by 10 m plots resulting in a rectangular block of 44 plots at the McCarty Spring enclosure and a rectangular block of 39 plots at the Winter Ridge enclosure. From the available plots at each study site, 32 plots were randomly chosen and randomly assigned a clipping treatment and year of treatment application.

3.4.2 Treatment Design

Bluebunch wheatgrass plants within each randomly chosen plot received one of four possible clipping treatments: 1) unclipped control, 2) the entire basal area of the plant was hand clipped to a 7.6 cm stubble height during the mid boot phenological stage, 3) one-half the basal area of the plant was hand clipped to a 7.6 cm stubble height during the mid boot phenological stage and, 4) the entire basal area of the plant was hand clipped to a 7.6 cm stubble height during the inflorescence emergence phenological stage. Each clipping treatment was replicated four times at each study site, using 16 of the available plots at each study site during 1993. The entire experiment was replicated in 16 new plots at each site during 1994.

3.4.3 Response Design

During early November of 1993 and 1994, forage samples were collected from plots treated during the previous spring. The forage samples were collected by randomly locating four 1 m² quadrats within each treated plot and clipping all the bluebunch wheatgrass plants within the quadrats to a 2.5 cm stubble height. All the material harvested from the four quadrats was combined into one composite forage sample per plot.

The forage samples were oven dried at 50° C until a constant dry weight (± 0.01 grams) was reached. The dried samples were then ground to pass through a 1 mm mesh screen. The percent crude protein in each sample was determined in duplicate using the Kjeldahl method as described by the Association of Official Analytical Chemists (AOAC 1980).

The percent *in vitro* dry matter digestibility in each sample was determined in triplicate using the techniques described by Tilley and Terry (1963). Findings by Campa et al. (1984) suggested *in vitro* digestibility analysis using rumen inoculum from wild elk would provide results more comparable to *in vivo* digestibility by wild elk than would *in vitro* digestibility analysis using rumen inoculum from domestic livestock. However, Welch et al. (1983) ran *in vitro* dry matter digestibility trials on 25 different forage species using rumen inocula from cattle (*Bos spp.*), domestic goats (*Capra spp.*), domestic sheep (*Ovis aries*), wild mule deer (*Odocoileus hemionus*), wild Rocky Mountain elk, and wild pronghorn (*Antilocapra americana*). No significant differences ($P < 0.05$) in *in vitro* dry matter digestibility due to rumen inoculum sources were detected. Distance from adequate laboratory facilities made it logistically impossible to utilize rumen inoculum from wild elk in the present study. The rumen inoculum used was a composite sample collected from two fistulated Hereford steers maintained on meadow hay.

The dry matter yield (kg/ha) from each plot was calculated based on the corrected dry weight of the composite sample from each plot. Two subsamples from each sample were oven dried at 100° C until 100% dry matter was reached. The percent dry matter of each sample was then calculated based on the average

difference between the initial and final weights of the two subsamples per sample. The percent dry matter value for each sample was used to correct the original sample weight to a 100% dry matter basis.

Crude protein, *in vitro* dry matter digestibility, and dry matter yield were compared between treatments, locations (study sites), and years using analysis of variance procedures (SAS 1988). Where differences were detected, Fisher's Least Significant Difference (LSD) procedure was used to make multiple comparisons of treatment means based on a 5% level of significance (SAS 1988, Montgomery 1991).

3.5 Results

3.5.1 Crude Protein

Highly significant treatment ($P < 0.0001$), location ($P < 0.0001$) and year ($P < 0.0001$) effects were detected for percent crude protein. There was also strong evidence ($P < 0.0001$) of a location*year interaction and weak evidence ($P = 0.0804$) of a treatment*location*year interaction. When compared across location and year, samples from the whole plant mid boot, half plant mid boot, and the inflorescence emergence clipping treatments were significantly higher ($P < 0.05$) in percent crude protein than the unclipped control (Fig. 3.1 and Table 3.1). The percent crude protein was similar ($P < 0.05$) between the whole plant mid boot and inflorescence emergence treatments but, both these treatments had higher percent crude protein ($P < 0.05$) than the half plant mid boot treatment.

Total crude protein (kg/ha) was significantly higher ($P < 0.05$) in the unclipped control than in the other 3 treatments (Table 3.1). The whole plant mid boot and half plant mid boot treatments produced similar ($P > 0.05$) levels of total crude protein while the inflorescence emergence treatment yielded the lowest ($P < 0.05$) amount of total crude protein.

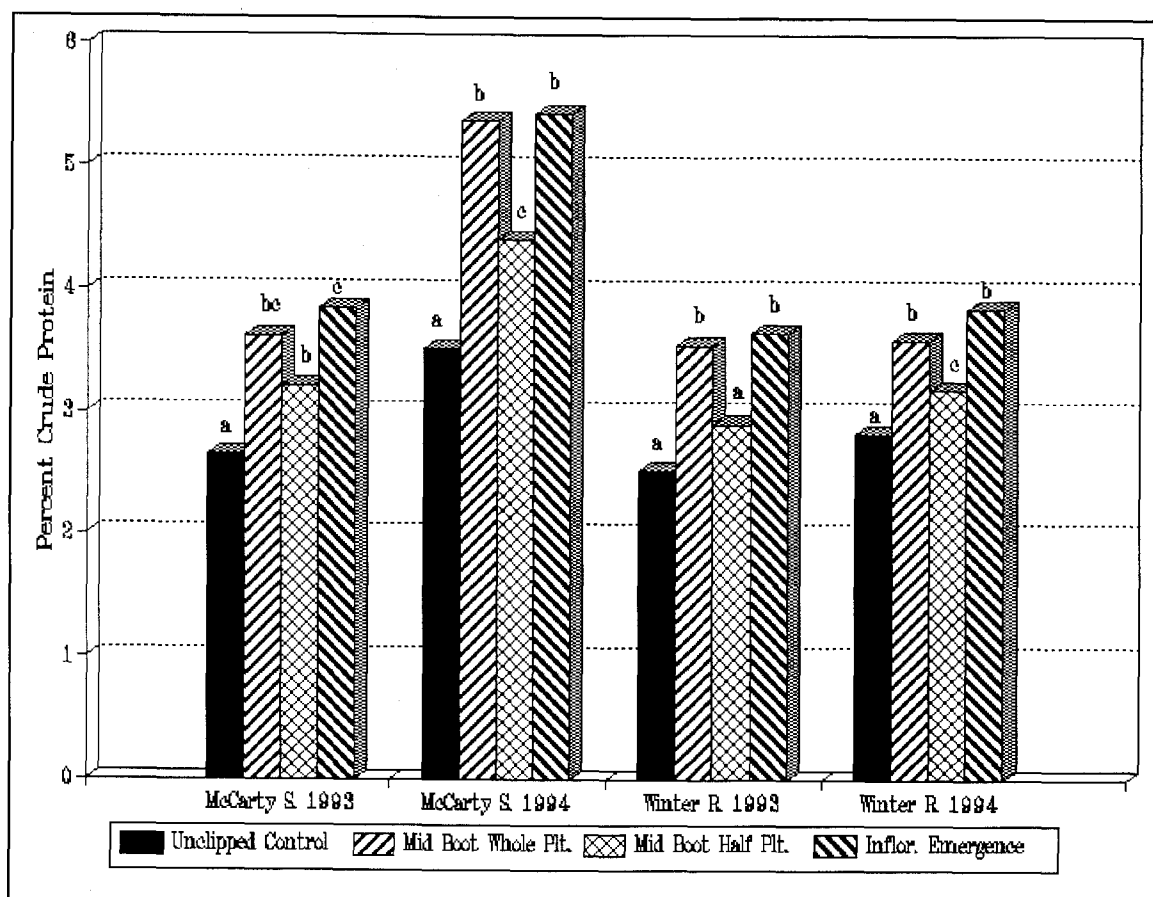


Figure 3.1 Percent crude protein of bluebunch wheatgrass from each of the four clipping treatments. Bars with different letter codes are significantly different within location/year combinations ($P < 0.05$).

Table 3.1 Forage nutritional value from each of the four clipping treatments.

Nutritional Value	Clipping Treatments				Std. Error of Mean
	Control	Mid Boot Whole Plt.	Mid Boot Half Plt.	Inflor. Emergence	
Crude Protein (%)	2.9 ^a (0.4404) ¹	4.0 ^b (0.8962)	3.4 ^c (0.6723)	4.2 ^b (0.8341)	0.3219
Digestibility (%)	38.7 ^a (3.3287)	44.4 ^b (3.2363)	41.6 ^c (3.3846)	44.5 ^b (3.6739)	2.3580
Dry Matter (kg/ha)	499.0 ^a (150.0876)	251.6 ^b (49.9015)	295.2 ^b (67.0624)	182.7 ^c (23.6534)	82.5568
Total CP (kg/ha)	14.5 ^a (5.6428)	10.0 ^b (2.1940)	10.1 ^b (2.6269)	7.6 ^c (1.4758)	2.6332
Total IVDMD (kg/ha)	194.7 ^a (64.7998)	111.6 ^b (23.1206)	123.6 ^b (33.1641)	80.9 ^c (7.4230)	31.4628

^{abc}Means followed by different letter codes are significantly different within rows ($P < 0.05$).

¹Standard deviations are enclosed in parentheses below each mean.

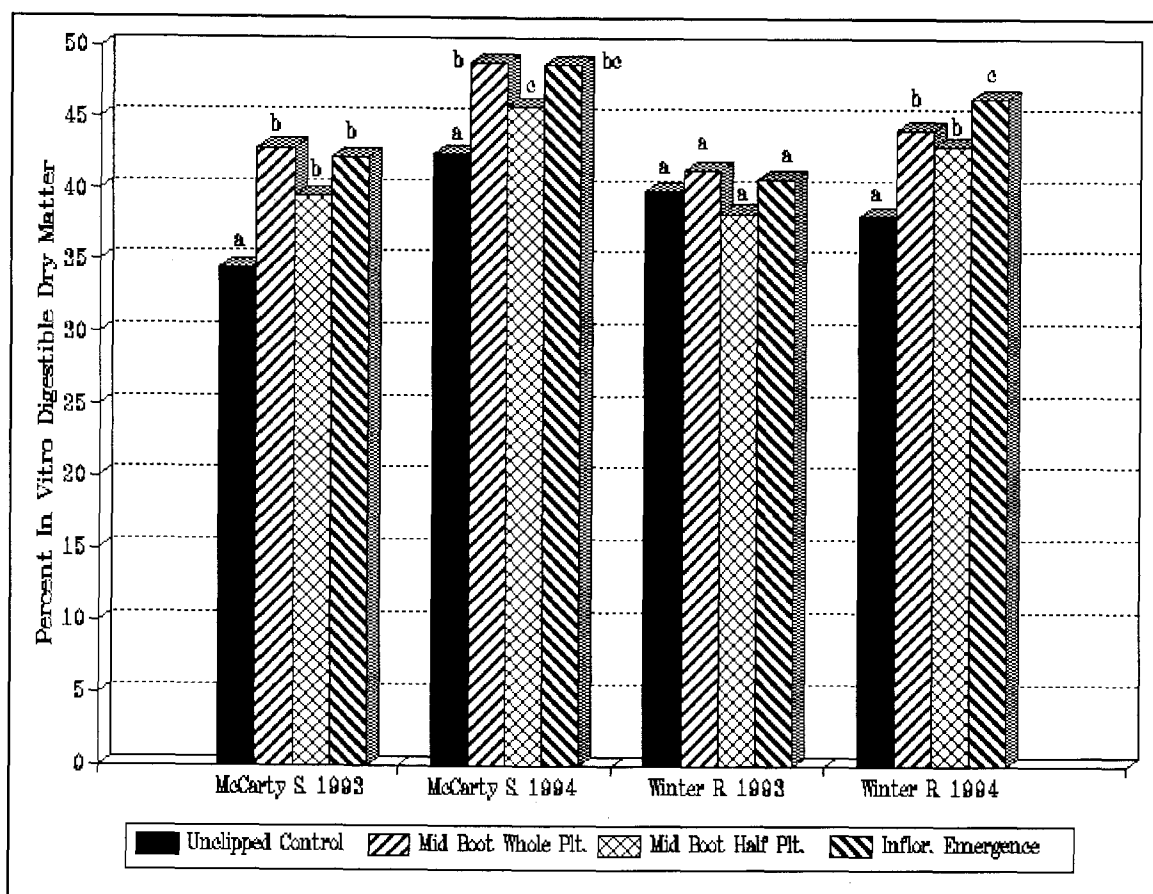


Figure 3.2 *In vitro* dry matter digestibility of bluebunch wheatgrass from the four clipping treatments. Bars with different letter codes are significantly different within location/year combinations ($P < 0.05$).

3.5.2 *in vitro* Dry Matter Digestibility

Similar to the percent crude protein, significant treatment ($P < 0.0001$), location ($P = 0.0128$), and year ($P < 0.0001$) effects were detected for percent *in vitro* dry matter digestibility. There was also strong evidence ($P = 0.0040$) of a location*year interaction and weak evidence ($P = 0.0575$) of a treatment*location*year interaction. When compared across year and location, samples from the whole plant mid boot and inflorescence emergence treatments had the highest ($P < 0.05$) percent *in vitro* dry matter digestibility (Table 3.1 and Fig 3.2). Samples from the half plant mid boot treatment had a moderate level of *in vitro* dry matter digestibility. The unclipped control samples had significantly lower ($P < 0.05$) *in vitro* dry matter digestibility than the samples from the other three treatments.

Total *in vitro* digestible dry matter (kg/ha) was highest ($P<0.05$) in the unclipped control (Table 3.1). The whole plant mid boot and half plant mid boot treatments produced similar ($P>0.05$) levels of total *in vitro* digestible dry matter. The inflorescence emergence treatment yielded the lowest ($P<0.05$) total *in vitro* digestible dry matter of the four treatments.

The *in vitro* dry matter digestibility of forage samples was converted to digestible energy for elk based on the following equation:

$$\text{DE kcal/g DM} = 0.051(\text{percent IVDMD}) - 0.7054 \text{ (Schommer 1978).}$$

Digestible energy data was then converted to metabolizable energy assuming 85% of digestible energy is metabolizable (Smith 1971, Thompson et al. 1973). The mean digestible energy and mean metabolizable energy from each treatment are listed in Table 3.2.

3.5.3 Dry Matter Yield

Significant treatment ($P<0.0001$), location ($P=0.0446$), and year ($P=0.0004$) effects were detected for dry matter yield. There was also very strong evidence ($P=0.0008$) of a treatment*year interaction and weak evidence ($P=0.1008$) of a location*year interaction. When analyzed across year and location, the dry matter yield of the unclipped control was significantly higher ($P<0.05$) than any of the other three treatments (Table 3.1 and Fig. 3.3). Dry matter yield from the whole plant mid boot and half plant mid boot treatments was similar but, both these treatments were higher ($P<0.05$) in dry matter yield than the inflorescence emergence treatment.

Table 3.2 The consumption rate required to meet the metabolizable energy requirements of a 200 kg elk on a 100% diet of bluebunch wheatgrass from each of the late spring clipping treatments.

Late Spring Clipping Treatments	<i>In Vitro</i> Dry Matter Digestibility	Digestible ¹ Energy	Metabolizable ² Energy	Consumption Rate Required ³	Percent of Maximum Consumption Rate
	------(%)-----	------(kcal/g DM)-----	------(kcal/g DM)-----	------(kg DM/day)-----	------(%)-----
Control	38.7	1.27	1.08	8.5	170
Mid Boot	44.4	1.56	1.32	6.9	139
Mid Boot Half	41.6	1.42	1.21	7.6	152
Inf. Emergence	44.5	1.56	1.33	6.9	138

¹Based on Schommer(1978) equation for conversion of IVDMD to DE.

²Assuming ME is 85% of DE (Smith 1971, Thompson et al. 1973).

³Based on a 5 kg/day consumption rate for a 200 kg elk (2.5% of body weight) Hobbs et al. 1982).

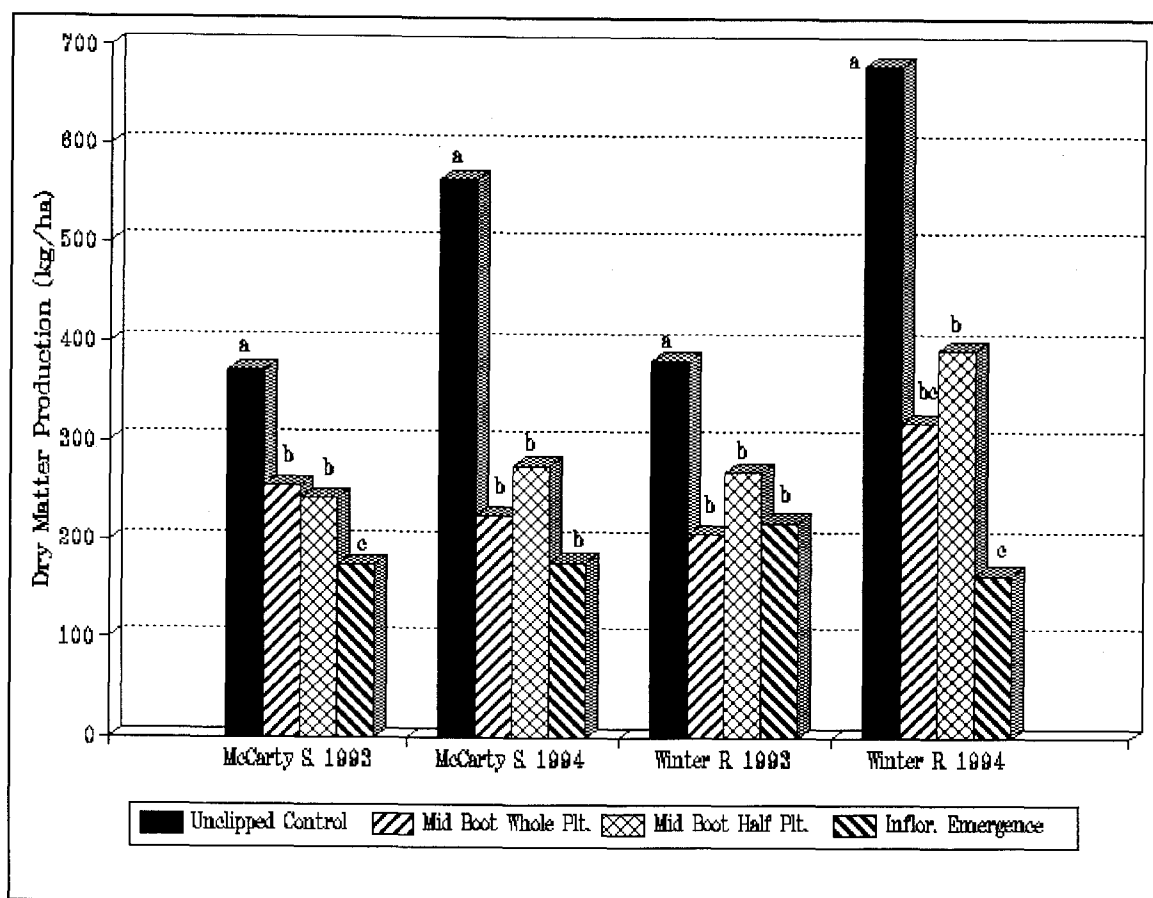


Figure 3.3 Dry matter yield in kg/ha of bluebunch wheatgrass from each of the four clipping treatments. Bars with different letter codes are significantly different within location/year combinations ($P < 0.05$).

3.6 Discussion

3.6.1 Defoliation and Plant Phenology

In northeastern Oregon, bluebunch wheatgrass plants clipped during the mid boot and inflorescence emergence phenological stages apparently have sufficient total nonstructural carbohydrate reserves and favorable growing season remaining following defoliation to produce regrowth of higher nutritional quality than forage from unclipped plants. However, dry matter yield and total nutrient yield were lower in bluebunch wheatgrass plants clipped during the mid boot or inflorescence emergence stages than in unclipped bluebunch wheatgrass plants.

Working on the same study sites as the present study, Westenskow-Wall et al. (1994) reported adequate growing season remained after clipping bluebunch wheatgrass just prior to the boot stage that the

resultant regrowth phenologically matured similarly to unclipped plants and the early winter forage quality was not improved by pre boot clipping.

Defoliation after the boot stage, when favorable growing conditions are rapidly declining, may result in very limited regrowth production and TNC recharge. Defoliation during the late dough stage and during the initiation of fall regrowth can critically reduce plant vigor (Trlica and Cook 1972, Daer and Willard 1981).

It appears the mid to late boot stage may be the only feasible phenological stage when spring conditioning of bluebunch wheatgrass can be effectively applied to improve the forage quality for winter grazers. Translocation of total nonstructural carbohydrates from foliar material to the root crowns and roots increases during the early boot stage (McIlvanie 1942, Daer and Willard 1981) with storage of carbohydrate reserves peaking during the late boot stage (Daer and Willard 1981). Energy demands for rapid elongation of reproductive culms and early seed development apparently cause the carbohydrate reserves in the roots and root crown to begin to decrease as the inflorescence emerges from the boot and the seeds enter the milk stage (Daer and Willard 1981). Defoliation during mid boot, when TNC reserves have been restored to greater than 50%, apparently allows bluebunch wheatgrass to draw on these TNC reserves from initiation of regrowth. Regrowth appears to be substantial enough to restore plant reserves with photosynthates to a point where plant vigor is not critically reduced (see chapter 4). The question of whether this regrowth of relatively higher forage quality is adequate for the nutritional needs of wintering elk is discussed below.

3.6.2 Effects of Hand Clipping vs. Grazing

Hand clipping may not effectively simulate the selective foraging behavior exhibited by grazing animals (Rickard et al. 1975). Generally, in clipping studies, all the tillers of the subject plants are defoliated to a prescribed level. Grazing animals defoliate grass plants less precisely than hand clippers. Plants grazed under the system suggested by Anderson and Scherzinger (1975) for spring conditioning elk winter range (i.e., moderate to heavy stocking and short duration) would likely contain grazed tillers of various stubble heights and often only a portion of the basal area of individual plants would be grazed leaving many tillers completely intact. Partial defoliation, as represented by the mid boot half plant clipping treatment may be more representative of moderate grazing effects than traditional whole plant clipping.

The diet quality of elk grazing bluebunch wheatgrass conditioned in the mid boot or inflorescence emergence stage may have been underestimated in this study. The forage samples analyzed in this study included stubble (5 cm) left from the clipping treatment, standing litter, and regrowth produced following clipping treatments. Elk probably would have selectively grazed the regrowth rather than the stubble and standing litter in each plant (Jourdonnais and Bedunah 1990). Consequently, the forage samples collected in this study may have contained more weathered and coarse material than actual elk diets. Elk grazing on

bluebunch wheatgrass conditioned following the procedures of this study would likely have diets of higher quality than the forage quality results from the present study suggest.

3.6.3 Bluebunch Wheatgrass as Winter Elk Forage

Clipping bluebunch wheatgrass during the mid boot or inflorescence emergence phenological stages produced regrowth of statistically higher forage quality than the control. However, the question of whether the clipping treatments produced large enough differences in forage quality to affect winter elk nutrition, productivity, and survival remains to be answered.

Published information on the nutritional requirements of free-ranging elk is very limited. Many studies have contributed to our knowledge of the diet composition (Mackie 1970, Kufeld 1973, Skovlin and Vavra 1979, Korfhage et al. 1980, Hobbs et al. 1981, MacCracken and Hansen 1981, Hobbs et al. 1983, Sheehy 1987) and diet quality of free-ranging elk (Ward 1971, Nowlin 1974, McArthur 1977, McReynolds 1977, Hobbs et al. 1982, Weber 1981, Rowland et al. 1983, Brooks et al. 1984, Bryant 1993, Westenskow-Wall et al. 1994). Unfortunately, without adequate knowledge of nutritional requirements, the influence of diet on the nutritional status, body condition and performance of free-ranging elk can only be roughly estimated (Nelson and Leege 1982, Swift 1983). In an attempt to bridge this gap of information, researchers have used our knowledge of ruminant digestive physiology and metabolism, daily activity patterns of wild elk, and nutritional requirements of ruminant livestock to predict the energy and nitrogen requirements of free-ranging elk (Gates and Hudson 1978, Hobbs et al. 1982, Nelson and Leege 1982, Swift 1983).

Combining their own elk activity budget data (collected using radiotelemetry activity collars) with activity energetics data from Gates and Hudson (1978), Hobbs et al. (1982) estimated a 200 kg cow elk required 9,185 kcal of metabolizable energy per day for maintenance and activity during winter. Assuming only negligible amounts of additional metabolizable energy would be required to offset the demands of gestation and thermoregulation during early November (Moen 1973, Nelson and Leege 1982, Parker and Robbins 1985), 9,185 kcal of metabolizable energy per day is probably a reasonable estimate of the total energy requirement for a gestating 200 kg cow elk in early November.

Table 3.2 describes the energy content of bluebunch wheatgrass forage from each clipping treatment and the dry matter consumption rate required under each treatment to meet the maintenance and activity requirements of a free-ranging 200 kg cow elk. Even on a diet made up of bluebunch wheatgrass forage from the inflorescence emergence treatment (i.e., the treatment yielding the highest content), the cow elk must consume an impossible 138% of her maximum consumption rate to meet her energy requirements for maintenance and activity. To avoid weight loss and declines in body condition during winter, this elk would have to supplement her diet with forage that exceeds maintenance quality to compensate for the submaintenance quality portion of the diet represented by bluebunch wheatgrass.

Assume bluebunch wheatgrass contributed 21% of the dry matter in the diet of a free-ranging cow elk (Sheehy 1987). Table 3.3 describes the metabolizable energy contribution of bluebunch wheatgrass forage from each of the clipping treatments to the winter diet of a free-ranging 200 kg cow elk on four different planes of nutrition. The differences in energy contribution between bluebunch wheatgrass forage from each clipping treatment increase as the plane of nutrition decreases assuming the diet composition remains constant. For a cow elk on a 100% maintenance diet, the proportional contribution of metabolizable energy from the inflorescence emergence treatment forage would be 2.8% greater than the energy contribution from the control treatment forage. On a 70% maintenance diet, the difference in energy contribution between the inflorescence emergence treatment and the control treatment forages increases to 4.1%. For elk wintering on rangelands where the nutritional quality of the forage is normally too low in energy to provide elk with a maintenance quality diet, the relatively small improvements in forage quality produced by the clipping treatments may be important to their nutritional status.

Based on data from Hungerford (1948), Geis (1950), Hobbs (1979), and Mould and Robbins (1981); Hobbs et al. (1982) estimated the maintenance requirement of nitrogen for a 200 kg elk during winter was 7.3 g of nitrogen per kg of forage dry matter. Assuming the maximum daily voluntary dry matter intake rate was 5 kg per day, to meet this requirement the elk would have to consume forages averaging at least 4.5% crude protein. The mean percent crude protein from the control treatment (2.9%) was substantially less than the maintenance requirement described by Hobbs et al. (1982). Although, significant differences ($P < 0.05$) existed between the control and the clipping treatments, none of the clipping treatments were effective in increasing the percent crude protein up to the maintenance level (Table 3.1).

As described above, relatively small improvements in forage quality may be important to the nutritional status of elk that normally winter on a submaintenance diet. Table 3.4 illustrates proportional nitrogen contribution of bluebunch wheatgrass forage from each of the clipping treatments to the diets of wintering elk on four different planes of nutrition. Similar to the metabolizable energy response discussed above, if the species composition of the diet is held constant, the differences in the proportion contribution of dietary nitrogen from each of the clipping treatments increases as the plane of nutrition decreases. For a cow elk on a 100% maintenance diet, the proportional contribution of dietary nitrogen from the inflorescence emergence treatment forage would be 6.2% greater than the nitrogen contribution from the control treatment forage. On a 70% maintenance diet, the difference in dietary nitrogen contribution between the inflorescence emergence treatment and the control treatment forages increases to 8.8%.

Table 3.3 Metabolizable energy contribution of bluebunch wheatgrass to the diet of a 200 kg elk on different planes of nutrition.

Clipping Treatments	Weighted ME Contribution ²	Percent ME Contribution ¹			
		100 % of Maintenance ³	90 % of Maintenance	80 % of Maintenance	70 % of Maintenance
	------(kcal)-----	------(%)-----			
Control	1144	12.5	13.8	15.6	17.8
Mid Boot	1403	15.3	17.0	19.1	21.80
Mid Boot Half	1278	13.9	15.5	17.4	19.9
Inf. Emergence	1409	15.3	17.0	19.2	21.9

¹Expresses the percent of the ME requirement contributed by bluebunch wheatgrass from each of the late spring clipping treatments to the diet of a 200 kg elk on four possible planes of nutrition.

²Metabolizable energy contribution of bluebunch wheatgrass assuming this species makes up 21% of a winter elk diet in northeastern Oregon (Sheehy 1987).

³Based on the metabolizable energy requirement of a 200 kg elk for 100% winter maintenance (9,185 kcal/day) (Hobbs et al. 1982).

Table 3.4 Dietary nitrogen contribution of bluebunch wheatgrass to the diet of a 200 kg elk on different planes of nutrition.

Clipping Treatment	Weighted N Contribution ²	Percent N Contribution ¹			
		100% of Maintenance ³	90% of Maintenance	80% of Maintenance	70% of Maintenance
	--(g/kg DM)--	------(%)-----			
Control	0.97	13.3	14.8	16.6	19.0
Mid Boot	1.36	18.7	20.8	23.4	26.7
Mid Boot Half	1.16	15.9	17.7	19.9	22.7
Inf. Emergence	1.42	19.5	21.6	24.3	27.8

¹Expresses the percent of the N requirement contributed by bluebunch wheatgrass from each of the late spring clipping treatments to the diet of a 200 kg elk on four possible planes of nutrition.

²Nitrogen contribution of bluebunch wheatgrass assuming this species makes up 21% of a winter elk diet in northeastern Oregon (Sheehy 1987).

³Based on the dietary N requirement of a 200 kg elk for 100% winter maintenance (7.3 g N/kg DM/Day) (Hobbs et al. 1982).

3.6.4 Effects on Palatability and Foraging Efficiency

Under the environmental conditions of the Blue Mountains of northeastern Oregon, there is apparently only a narrow phenological window in which to improve the forage quality of bluebunch wheatgrass by livestock grazing without critically reducing forage quantity. In the present study the mid boot and inflorescence emergence clipping treatments produced only relatively small improvements in the winter nutritional value of bluebunch wheatgrass forage compared to the control and it seems questionable whether wintering elk would alter their distribution patterns in response to this level of forage quality improvement. However, several researchers have reported substantial increases in winter elk utilization on areas receiving prescribed livestock grazing (Anderson and Scherzinger 1975, Jourdonnais and Bedunah 1990, Frisna and Morin 1991). Notably, the phenological timing of these livestock grazing treatments was much less precise than the clipping treatments in the present study. The elk utilization responses observed in these earlier studies were probably related to a combination of interacting forage plant responses to the livestock grazing treatments. Reduction of standing litter accumulation (Anderson and Scherzinger 1975, Peek et al. 1979, Willms et al. 1980a, Willms et al. 1980b, Jourdonnais 1985, Gordon 1988), reduction in the number of reproductive culms per plant (Ganskopp et al. 1992) and improvements in the nutritional quality of the forage probably all influenced the elk utilization responses in these studies. Livestock grazing treatments used to reduce the standing litter and reproductive culms could be applied within a fairly wide phenological window and may substantially increase the accessibility of palatable forage to feeding elk (Willms et al. 1980b, Jourdonnais 1985).

In a forage conditioning study conducted on a bunchgrass/sagebrush rangeland in eastern Oregon, forage samples from ungrazed plots and plots grazed by cattle in the spring were collected in the fall by clipping (i.e., total available forage) and by the use of esophageal-fistulated steers (Pers. Comm., Tim Delcurto, Eastern Oregon Agr. Exp. Sta., September 13, 1995). Although the clipping samples indicated a forage quality difference existed between the grazed and ungrazed plots on a total available forage basis, the fistulated steers appeared to be selectively grazing forage of similar quality from both the grazed and ungrazed plots and this selected forage was higher in quality than the total available forage in ungrazed plots. The steers were probably selectively grazing the phenologically younger tillers from the current year's growth of individual plants and avoiding reproductive culms and standing litter (Ganskopp et al. 1992). It is probably reasonable to assume elk wintering on bunchgrass-dominated rangelands would exhibit selective grazing behavior similar to the beef steers described above.

The energy expended while foraging represents a substantial portion of the daily energy budget of a wintering elk (Hobbs et al. 1982, Nelson and Leege 1982, Wickstrom et al. 1984). Consequently, foraging efficiency (i.e., energy expenditure/unit of nutrient ingested) may strongly influence the ability of an elk to meet its energy requirements during winter. As described above, it may be possible for elk to obtain forage of the same quality from conditioned and unconditioned forage by selective grazing. Forage conditioning may not only

enhance the overall nutritional quality of the forage by delaying plant phenology but also increase the accessibility of phenologically younger portions of the plants by removing obstructing litter and unpalatable culms, decrease foraging time and distance traveled/unit of nutrient ingested, and decrease time exposed to predators and harsh environmental conditions. For elk that normally winter on a relative low plane of nutrition, even small increases in foraging efficiency may be critically important.

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Chapter 4

Effect of Late Spring Defoliation on the Vigor and
Survival of Bluebunch Wheatgrass on Elk Winter Range

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4. EFFECT OF LATE SPRING DEFOLIATION ON THE VIGOR AND SURVIVAL OF BLUEBUNCH WHEATGRASS ON ELK WINTER RANGE

4.1 Abstract

Bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) was hand clipped to a 7.6 cm stubble height in early June under each of three different phenological stage/intensity level combinations: 1) mid boot/whole plant clipped, 2) mid boot/one-half of the plant's basal area clipped, and 3) inflorescence emergence/whole plant clipped. In early November, tagged plants from each of the early June clipping treatments were hand clipped to a 2.5 cm stubble height. The live basal area of bluebunch wheatgrass plants was significantly influenced by late spring clipping treatments ($P < 0.0001$). Plants having their entire basal area clipped to a 7.6 cm stubble height during the mid boot or inflorescence emergence stages exhibited negative changes in basal area while plants left unclipped or having only one half their basal area clipped to a 7.6 cm stubble height during the mid boot stage exhibited positive changes in basal area ($P < 0.05$). The effect of late spring and early winter clipping treatment combinations on plant vigor was not significantly different than the effect produced by late spring only clipping ($P = 0.1257$). Percent mortality was not significantly related to any of the variables measured ($P < 0.05$). The experiment-wide percent mortality was only 0.2%.

4.2 Introduction

Many authors have suggested livestock could be used as an effective tool for improving forage for elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) (Jensen et al. 1972, Anderson and Scherzinger 1975, Malechek et al. 1978, Smith et al. 1979, Willms et al. 1980, Willms et al. 1981, Jourdonnais and Bedunah 1990, Frisina and Morin 1991). Anderson and Scherzinger (1975) reported late spring livestock grazing could be used to improve the forage quality on elk winter ranges dominated by perennial bunchgrasses such as Idaho fescue (*Festuca idahoensis* Elmer) and bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith). Anderson and Scherzinger (1975) cautioned grazing of bunchgrass during the late spring required special management attention since this time period represented a critical period in plant phenology and improper grazing during this period could result in little or no regrowth production and reduced plant vigor. By carefully managing the intensity, duration and timing of defoliation, bunchgrass plants may be induced to produce regrowth of higher winter forage quality than undefoliated plants thus benefiting wintering elk without critically reducing plant vigor (Anderson and Scherzinger 1975).

Although, the grazing management guidelines suggested by Anderson and Scherzinger (1975) have been adopted and widely used, the complex interactions making up a plant's physiological response to defoliation are not fully understood and an optimal combination of intensity, duration, and timing of livestock

grazing for winter range conditioning has not been firmly established for bluebunch wheatgrass-dominated rangelands.

The negative effects of defoliation on the vigor of bluebunch wheatgrass may be minimized by managing for taller stubble heights (i.e., greater than 5 cm), initiating grazing late enough in plant phenology to allow sufficient storage of total nonstructural carbohydrate (TNC) reserves prior to defoliation, and ending grazing early enough in the growing season to allow replacement of photosynthetic tissue and lost TNC reserves prior to temperature- and drought-induced summer quiescence (Stoddart 1946).

The amount and type of residual tissue remaining after defoliation greatly influences subsequent plant vigor (Stoddart 1946). Caldwell et al. (1981) reported culms of bluebunch wheatgrass played a significant role in photosynthetic capacity of the plant. In partially defoliated plants green stubble, culms stripped of leaves (Caldwell et al. 1981) and intact tillers may all provide a substantial photosynthetic contribution to the plant decreasing the negative effects of defoliation compared to completely defoliated plants. Although, Anderson and Scherzinger (1975) were somewhat vague in their description, the desired level of defoliation for conditioning bunchgrass forage appears to be to moderate with the basal area of most plants only being partially defoliated. This type of defoliation could be accomplished by moderate to heavily stocked, short duration grazing (Anderson and Scherzinger 1975).

Bluebunch wheatgrass appears to be most susceptible to reductions in vigor during the late spring (Stoddart 1946, Blaisdell and Pechanec 1949, Wilson et al. 1966, Mueggler 1975). However, Anderson and Scherzinger (1975) postulated late spring may be the most effective time to use livestock grazing to improve the forage quality of bunchgrasses for elk and other winter grazers. Although, defoliation of bluebunch wheatgrass during the early spring apparently does not seriously affect plant vigor since a sufficient amount of growing season remains for regrowth and replenishment of TNC reserves needed for overwintering, the phenology and forage quality of the regrowth produced is similar to undefoliated plants (Pitt 1986, Bryant 1993, Westenskow-Wall 1994). Consequently, little actual benefit for winter grazers is achieved by early spring grazing. Likewise, late season grazing (i.e., mid to late summer) of bluebunch wheatgrass apparently does not critically reduce plant vigor since total nonstructural carbohydrate storage is at or near the annual high (McIlvanie 1942) during this period. However, production of regrowth as replacement of lost photosynthetic tissue and as forage for winter grazers is seriously limited by summer quiescence. Late spring defoliation (i.e., during the boot and inflorescence emergence stages) can dramatically reduce the vigor of bluebunch wheatgrass because TNC storage is at the annual low during the early boot stage (McIlvanie 1942, Daer and Willard 1981) and the relatively short length of growing season remaining after defoliation may seriously limit restoration of TNC reserves prior to summer quiescence. However, TNC storage in the roots and root crown increases rapidly during the boot stage and is at a relatively high level by the mid to late boot stage (McIlvanie 1942, Daer and Willard 1981). Defoliation of bluebunch wheatgrass during the mid boot stage may allow enough growing season for production of regrowth in amounts adequate to restore lost TNC reserves but, the

growing season should also be short enough that the phenology of the regrowth would be much younger and the forage quality higher than undefoliated plants at the onset of summer quiescence (see chapter 3).

Our objective was to examine the effect of late spring clipping on the vigor and survival of bluebunch wheatgrass. We tested the hypothesis a single, partial defoliation (50%) of the basal area of individual bluebunch wheatgrass plants during mid boot phenological stage represented an optimal combination of phenological timing, duration and intensity of defoliation for producing regrowth of high forage quality and ample forage quantity for wintering elk without critically affecting plant vigor and survival.

4.3 Study Area

The study was conducted during 1993 and 1994 within USDA Forest Service big game winter range management areas located near Starkey Experimental Forest and Range in the Blue Mountains of northeastern Oregon. Two study sites, McCarty Spring and Winter Ridge, selected for use in two previous studies (Bryant 1993, Westenskow-Wall 1994), were utilized for the present study (see chapter 3). There were six criteria used in the selection of these sites: 1) location on an open ridge, 2) southerly to westerly aspect, 3) grassland vegetation type, 4) sufficient density of bluebunch wheatgrass plants for effective sampling, 5) location on public land, and 6) a consistent history of winter elk use. The McCarty Spring site was located at 1,274 m in elevation with a gently sloping (0 to 5%) westerly aspect. The Winter Ridge site had a gently sloping (0 to 7%) south-southwesterly aspect at 1,366 m in elevation.

The plant communities on both sites was classified as bunchgrass on shallow soil, gentle slopes, GB-49-11 (Hall 1973). Dominant perennial species were bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass (*Poa secunda* Presl.), and western yarrow (*Achillea millefolium* L.). Soils at each site were extremely stony to very cobbly, loams and silt-loams of the Anatone-Bocker complex (Dyksterhuis and High 1985, Bryant 1993).

The climate was continental with cold winters and warm summers. Precipitation occurred primarily as winter snow and spring rain. The occurrence and amount of fall precipitation has historically been unpredictable. Annual precipitation totals for 1993 and 1994 at Starkey Experimental Forest and Range, less than 15 km away from both study sites, were 59.7 cm and 50.7 cm, respectively. The ten year average (1986 to 1995) for annual precipitation at Starkey Experimental Forest and Range was 54.8 cm (Unpub. data, on file at Forestry and Range Sciences Laboratory, La Grande, OR).

Skovlin (1991) reported Indian horses were probably the first domestic animals to graze in the vicinity of the study sites. The Cayuse Indians, who likely used the area for hunting, fishing, and root gathering, first acquired horses between 1710-1720. Livestock grazing has occurred in the area from 1843 to present. Pioneers traveling along the Oregon Trail began to graze livestock in the study area starting in 1843. Between 1864 to 1905 the area was used as year-round livestock pasture by local homesteaders and as a driveway for cattle being taken to markets to the east. Livestock use in the area was reduced somewhat following the

establishment of the National Forest Reserves in 1905 (Skovlin 1991). However, it was not until 1940 that livestock grazing in the area was reduced to levels comparable to those used currently (Bryant 1993). The McCarty Spring study site was grazed primarily by cattle until 1949, after which sheep grazing predominated. The Winter Ridge study site was grazed by sheep until 1962 and has been grazed by cattle since that time. An 0.5 ha livestock enclosure was constructed at each study site during the summer of 1986. The clipping experiments of the two previous studies (Bryant 1993, Westenskow-Wall et al. 1994) and the present study were conducted within these enclosures.

4.4 Methods

4.4.1 Experimental Design

A split plot experimental design was used. At each study site, the area within the livestock enclosure (excluding a 10 m wide fence buffer zone) was divided into 10 m by 10 m whole plots. Thirty-two of the whole plots available at each study site were randomly assigned a late spring clipping treatment and year of application as described in chapter 3. Sixteen bluebunch wheatgrass plants within each whole plot were selected randomly as subplots. The random selection of subplots was restricted to vigorous bluebunch wheatgrass plants with distinct boundaries. The subplots were randomly assigned an early winter clipping treatment as described below. Each subplot was tagged and photographed for later identification.

4.4.2 Treatment Design

Starting in 1993, the 32 selected whole plots at each study site were randomly assigned to one of four late spring clipping treatments: 1) control, 2) mid boot/whole plant, 3) mid boot/half plant, and 4) inflorescence emergence (see chapter 3). Bluebunch wheatgrass plants within the whole plots assigned the control treatment were left unclipped. Under the mid boot/whole plant treatment the entire basal area of all the bluebunch wheatgrass plants within the whole plot was hand clipped to a 7.6 cm stubble height during the mid boot phenological stage. One half the basal area of all the individual bluebunch wheatgrass plants was clipped to a 7.6 cm stubble height during the mid boot stage under the mid boot/half plant treatment. The entire basal area of bluebunch wheatgrass plants within whole plots assigned the inflorescence emergence treatment were clipped to a 7.6 cm stubble height during the inflorescence emergence phenological stage. Each late spring clipping treatment was replicated 4 times per year at each site.

Eight of the sixteen subplots per whole plot were randomly assigned to a 2.5 cm hand clipping treatment applied during early November. This clipping treatment was designed to simulate the effects of early

winter elk utilization on the vigor of plants defoliated during the previous spring. The remaining eight subplots per whole plot were left unclipped as a subplot control. The entire experiment was repeated during 1994 on the remaining 16 whole plots at each study site.

4.4.3 Response Design

The percent mortality and percent change in basal area of subplot bluebunch wheatgrass plants were evaluated during the hard seed phenological stage approximately one year following the application of the late spring clipping treatments (i.e., August 1994 and August 1995). The plants were visually inspected to determine the percent mortality. If there were no live tillers, the plant was considered dead. The basal area of the subplot plants was used to assess plant vigor and was expressed as the product of the maximum length and the maximum width of the individual plants measured at ground level. The area of any dead spots within the basal area of each plant were similarly measured and this area value was subtracted from the total basal area to yield the live basal area of the plant. The percent change in live basal area was assessed by comparing an initial basal area measurement to the final measurement described above. The initial measurement was taken during the hard seed phenological stage approximately 2 months after the application of the late spring clipping treatments. Subplot plants classified as dead during the final basal area measurement were recorded as having a negative 100% change in basal area.

Percent mortality and percent change in basal area were compared between subplot treatments, whole plot treatments, locations (study sites), and years using analysis of variance procedures (SAS 1988). Where differences were detected, Fisher's Least Significant Difference (LSD) procedure was used to make multiple comparisons of treatment means based on the 5% level of significance (SAS 1988, Montgomery 1991).

4.5 Results

4.5.1 Percent Mortality

No significant differences in percent mortality of subplot plants were found between whole plot treatments ($P=0.5766$), subplot treatments ($P=1.0$), study sites ($P=1.0$), or years ($P=0.1638$). Only two subplot plants died during the study and both were in whole plots treated during the second year (1994). The first plant received both the mid boot/whole plant clipping treatment and the early winter clipping treatment. The second plant was clipped during the inflorescence emergence stage but was not clipped in early winter. The experiment-wide mortality rate was only 0.2%.

4.5.2 Percent Change in Basal Area

The late spring clipping treatments (i.e., whole plot treatments) produced highly significant differences ($P < 0.0001$) in the percent change in basal area of subplot plants (Table 4.1). In 1993 at both the McCarty Spring and Winter Ridge sites, plant vigor under the mid boot/half plant whole plot treatment was significantly greater ($P < 0.05$) than plant vigor under the other three whole plot treatments (Figure 4.1). The mid boot/whole plant treatment reduced plant basal area compared to the whole plot control ($P < 0.05$) at the McCarty Spring site in 1994.

There was weak evidence of a subplot treatment effect (i.e., early winter clipping) on the percent change in basal area of subplot plants ($P = 0.1257$). We used the Bonferroni method to make multiple comparisons of subplot treatment effects on the subplot plants clipped under the four whole plot treatments. Subplot plants receiving only the mid boot/half plant treatment had a significantly larger increase in basal area ($P = 0.0480$) than did subplot plants receiving the combination of mid boot/half plant and early winter clipping (Table 4.1, Figures 4.1 and 4.2).

Highly significant differences in the plant vigor response ($P < 0.0001$) were detected between study sites. Clipping treatments generally had less negative effects on plant vigor at the Winter Ridge study site ($P < 0.05$). The inflorescence emergence whole plot/early winter subplot treatment combination (Figure 4.2) produced significant reductions in the basal area of subplot plants at the McCarty Spring site during 1994 compared to the control ($P < 0.05$). There was no statistical evidence of interactions between study site and whole plot ($P = 0.9733$) or subplot treatments ($P = 0.4173$). No significant year effects were detected ($P = 0.3492$). However, there was suggestive evidence of an interaction between the whole plot treatment and year ($P = 0.0777$). Plants receiving whole plot treatments in 1994 seemed to be less vigorous than plants treated in 1993. This vigor response may have been related to the higher precipitation received in 1993 compared to 1994.

Table 4.1 Comparison of whole plot and subplot treatment effects on the percent change in basal area of bluebunch wheatgrass.

Subplot Treatments	Whole Plot Clipping Treatments				Std. Error of Mean
	Control	Mid Boot Whole Plt.	Mid Boot Half Plt.	Inflor. Emergence	
	------(%)-----				
Without Simulated Winter Elk Grazing	5.2 ^{ax} (16.6679) ¹	-7.0 ^{bx} (8.7033)	18.6 ^{ax} (12.8136)	-7.8 ^{bx} (4.3592)	16.70
With Simulated Winter Elk Grazing	4.31 ^x (13.7847)	-8.5 ^x (14.2626)	6.0 ^y (11.0880)	-13.1 ^x (15.5333)	19.8808

¹Standard deviations are enclosed within parentheses below the means.

^{ab}Means with different "a" or "b" letter codes within the first row represent significantly different whole plot treatment effects (P<0.05).

^{xy}Means with different letter codes "x" or "y" within columns represent significantly different subplot treatment effects (P<0.05).

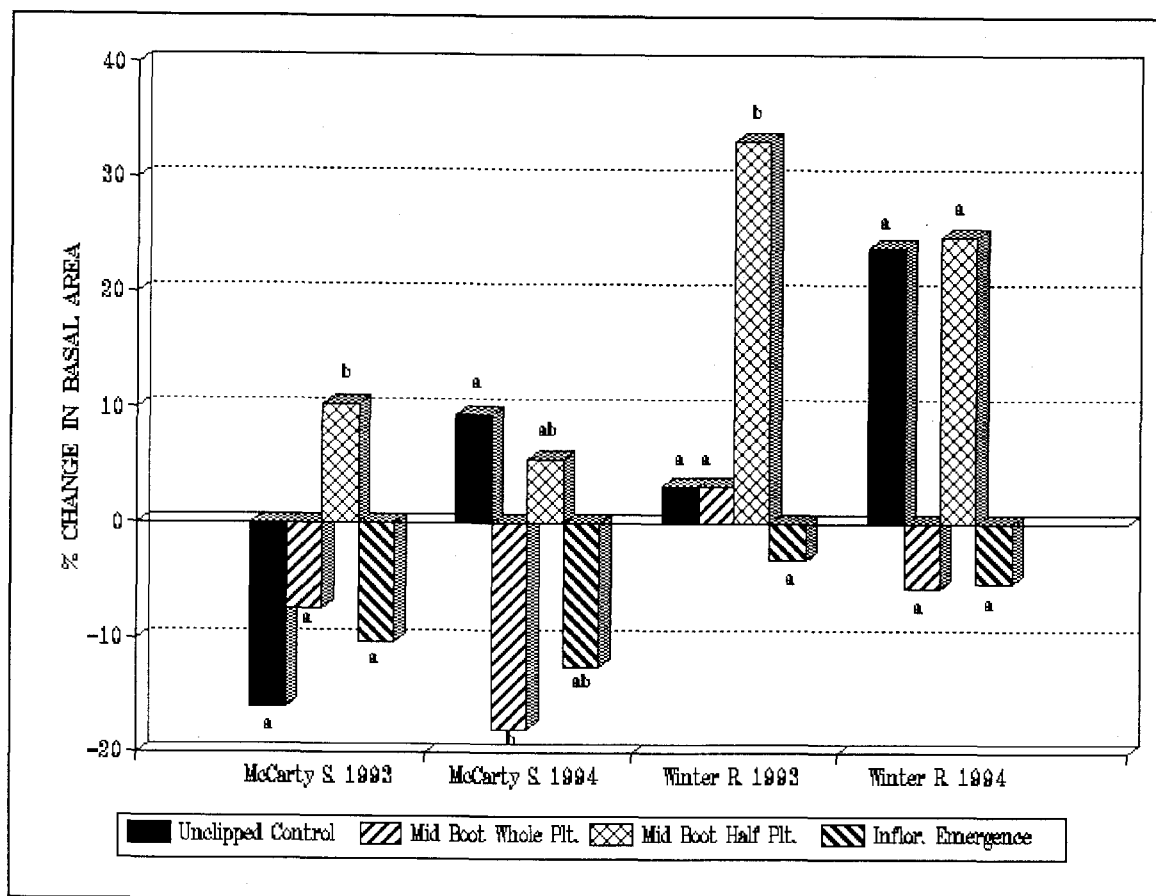


Figure 4.1 Percent change in basal area of bluebunch wheatgrass plants receiving the whole plot treatments (i.e., late spring clipping) and receiving the control subplot treatment (i.e., no early winter clipping). Bars with different letter codes are significantly different within location/year combinations ($P < 0.05$).

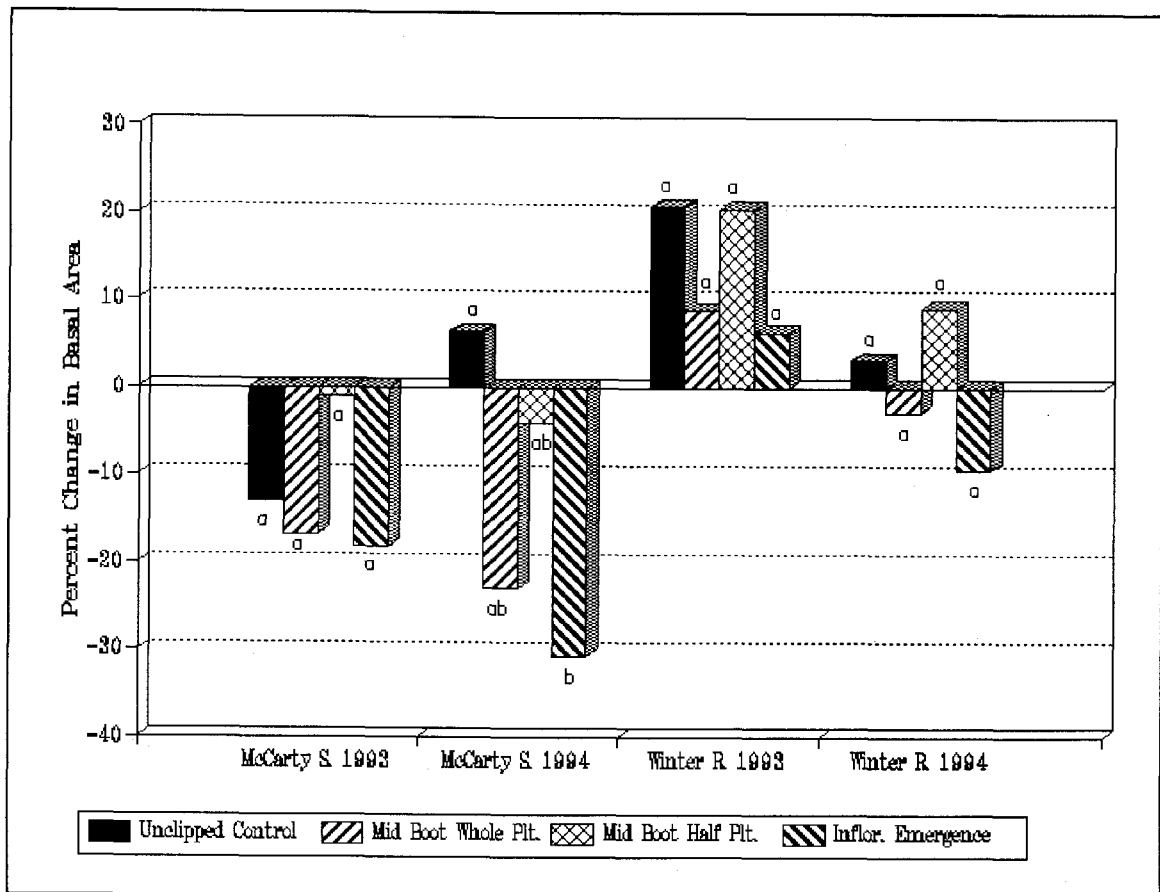


Figure 4.2 Percent change in basal area of bluebunch wheatgrass plants receiving the whole plot treatments (i.e. late spring clipping treatments) and the subplot clipping treatment (i.e. simulated early winter elk use). Bars with different letter codes are significantly different with location/year combination $P < 0.05$.

4.6 Discussion

4.6.1 Sustainable Grazing

Attempts to tailor grazing management systems to enhance the forage quality on elk winter range should emphasize the sustainability of the forage resource. Findings from the present study support the suggestions made by Anderson and Scherzinger (1975) that one potentially useful grazing management system for forage conditioning may be one designed to achieve a moderate level of defoliation of bluebunch wheatgrass plants during the boot stage. If one half the basal area of individual bluebunch wheatgrass plants was grazed to a stubble height of 7.6 cm by livestock then, the nutritional quality of the winter forage from

these plants may be significantly enhanced compared to ungrazed plants (see chapter 3) and the vigor of the grazed plants similar to ungrazed plants.

4.6.2 Effects of Competition on Vigor

The effect of competing plant species on the nutritional quality and vigor of bluebunch wheatgrass was not directly evaluated in this study. Mueggler (1972) found the partial reduction of competition by neighboring plant species reduced the negative effect defoliation had on the vigor of bluebunch wheatgrass plants. In the present study, only bluebunch wheatgrass plants were clipped. Other plant species occurring in the experimental plots were not disturbed except for a slight amount of trampling damage occurring during the clipping treatments. Consequently, bluebunch wheatgrass plants receiving the clipping treatments may have been placed under greater competitive disadvantage than would occur in an actual grazing situation. Effects on plant vigor may have been somewhat exaggerated in this study.

4.6.3 Cumulative Effects of Repeated Clipping

Although, the clipping treatments resulted in very limited mortality of the subplot plants, this study did not examine the effect this level of defoliation would have on plant vigor and percent mortality if applied during several consecutive years.

Bluebunch wheatgrass recovers vigor relatively slow (Mueggler 1975, Caldwell et al. 1981). Successive defoliations over several consecutive years may have a cumulative effect on plant vigor (Wilson et al. 1966, Rickard et al. 1975). Anderson and Scherzinger (1975) pointed out forage conditioning treatments probably should be applied under a rotation grazing system. However, forage conditioning under a rigid grazing system may not be as effective as a grazing management strategy which emphasizes maintenance of plant vigor and is flexible enough to response to annual fluctuations in forage and environment conditions. As discussed above, forage conditioning treatments generally cause stress to the forage plants. To maintain healthy, vigorous plants under a forage conditioning regime, these plants must be allowed time to recover from the stress of defoliation. A possible grazing management strategy for late spring forage conditioning should include several options for plant recovery following defoliation. One option for plant vigor recovery after late spring forage conditioning treatments may be early spring grazing during the following year. Early spring grazing seems to have a minimum effect on the vigor of bluebunch wheatgrass if defoliation is terminated early enough in the growing season to allow complete phenological maturation before summer quiescence (Stoddard 1946, Blaisdell and Pechanec 1949, McLean and Wikeem 1985). A second option might be grazing deferment until late summer prior to the initiation of fall regrowth or until after heavy frosts begin to limit growth in the late fall. Under this option, plants grazed in the late spring would have an entire growing season during the

following year to recover any losses of vigor. Cured leaves and culms may be removed by late season grazing, reducing the formation of "wolf plants" that might develop from the accumulation of standing litter. A third option could be a year-long rest from grazing. Anderson and Scherzinger (1975) recommended plants grazed in the late spring for two consecutive years should be rested from grazing for at least one year. However, one year of rest may reestablish some of the "wolfy" characteristics in these bunchgrass plants, especially under moderate grazing (i.e., as in mid boot/half plant clipping treatment). Again, choice of the year-long rest option or any other option for vigor recover following late spring forage conditioning should be based a flexible and responsible grazing management strategy.

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Chapter 5

Effect of Late Spring Livestock Grazing
on the Winter Forage quality
of Bluebunch Wheatgrass, Idaho Fescue and Elk Sedge

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5. EFFECT OF LATE SPRING LIVESTOCK GRAZING ON THE WINTER FORAGE QUALITY OF BLUEBUNCH WHEATGRASS, IDAHO FESCUE AND ELK SEDGE

5.1 Abstract

A late spring sheep grazing treatment and a grazing exclusion treatment were applied to bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), and elk sedge (*Carex geyeri* Boott) in different vegetation types. Improvement in the percent crude protein for all three species was observed in winter samples from grazing treatment plots compared to plots where grazing was excluded. *In vitro* dry matter digestibility also increased in winter samples of bluebunch wheatgrass from grazed plots compared to ungrazed plots. The number of reproductive culms/bluebunch wheatgrass or Idaho fescue plant was similar between grazing and grazing exclusion treatments. The presence of forest canopy produced statistically significant effects on the crude protein content of elk sedge compared to areas lacking forest canopy. Differences in forage quality between an early winter (November) sampling period and a late winter (March) sampling period were detected for all three species.

5.2 Introduction

Urban expansion and agricultural development on traditional big game winter range has altered the winter distribution of Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) in many areas of the West (Vavra 1992). Many elk now winter on what were traditionally spring-fall foothill rangelands (Skovlin and Vavra 1979, Sheehy 1987, Sheehy and Vavra 1995, Sheehy and Vavra 1996). Much of this spring-fall range is located on private lands. Losses of livestock forage to winter and spring elk use on these private rangelands has prompted concern among private land owners (Vavra 1980, Nelson 1982, Lacey et al. 1993). Habitat enhancement projects on existing publicly-owned winter big game range may provide an effective means of increasing winter elk use of public lands and reducing conflict generated by elk damage to private lands.

Two native perennial grasses, bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) and Idaho fescue (*Festuca idahoensis* Elmer) dominate the grasslands of big game winter ranges in northeastern Oregon. Anderson and Scherzinger (1975) suggested spring livestock grazing of bluebunch wheatgrass and Idaho fescue may enhance the forage quality of these bunchgrasses for wintering elk. On a publicly-owned wildlife management area in northeastern Oregon which had previously been closed to livestock grazing, Anderson and Scherzinger (1975) reported wintering elk numbers had increased from 320 to 1,191 head after 10 years under a rest-rotation cattle grazing management system which emphasized late spring grazing to condition the forage for winter elk use. Other researchers have reported increases in elk use

following cattle grazing treatments on winter ranges where bluebunch wheatgrass and Idaho fescue are dominant species (Jourdonnais 1985, Jourdonnais and Bedunah 1990, Frisina and Morin 1991).

Anderson and Scherzinger (1975) hypothesized grazing bluebunch wheatgrass and Idaho fescue in the late spring would delay the phenological development of grazed plants allowing them to cure at a more nutritious phenological stage than would ungrazed plants. Consequently, late spring grazing of bluebunch wheatgrass and Idaho fescue would provide higher quality forage for wintering elk. Several researchers have tested this hypothesis for bluebunch wheatgrass using clipping experiments (Pitt 1986, Bryant 1993, Westenskow-Wall et al. 1994).

Elk sedge (*Carex geyeri* Boott) is a dominant graminoid species in forested vegetation types on foothill big game winter ranges of northeastern Oregon. Elk sedge often makes a considerable portion of the winter diets of elk on these rangelands (Skovlin and Vavra 1979, Sheehy 1987). However, the effects of spring defoliation on the winter forage quality of elk sedge have not been studied.

Our objective was to test the forage conditioning hypothesis proposed by Anderson and Scherzinger (1975) by measuring the forage quality response of bluebunch wheatgrass and Idaho fescue grazed by livestock in the late spring under practical management conditions. Because elk sedge formed a large portion of the winter diet of elk in this region, we also tested the forage quality response of this species to late spring livestock grazing.

5.3 Study Area

The study was conducted from 1992 to 1995 within a 2073 ha study area adjacent to Starkey Experimental Forest and Range in the Blue Mountains of northeastern Oregon. The study area was located within the McCarty Spring Big Game Winter Range Vehicle Closure Area established by the USDA Forest Service to minimize motor vehicle disturbance of wintering big game. The study area has been closed to motor vehicle traffic during winter and early spring (early December to early April) since 1984. The study area was also located within the McCarty Spring sheep allotment managed by the USDA Forest Service. Sheep grazed the study area from early June until early October.

The elevation of the study area extended from 1170 m to 1536 m. The study area was dissected by several, nearly parallel drainages flowing from southwest to northeast. The topography of the lower elevation, northern half of the study area consisted of broad open ridges bordered by shallow stringer drainages. Vegetation on the open ridges was dominated by bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass (*Poa secunda* Presl.), and western yarrow (*Achillea millefolium* L.). The ecotone vegetation between the ridges and stringer drainages contained a ponderosa pine (*Pinus ponderosa* Dougl.) overstory with a Idaho fescue/elk sedge/bluebunch wheatgrass understory. The vegetation in the stringer drainages consisted of a Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco.) /grand fir (*Abies grandis* [Douglas] Forbes) overstory,

with a mallow ninebark (*Physocarpus malvaceus* [Greene] Kuntze)/common snowberry (*Symphoricarpos albus* [L.] Blake)/oceanspray (*Holodiscus discolor* [Pursh] Maxim.) midstory, and an elk sedge/pinegrass (*Calamagrostis rubescens* Buckl.) understory. The higher elevation, southern half of the study area consisted of deeper canyons and forested ridgetops. The vegetation on the northerly and easterly slopes of the canyons consisted of a Douglas-fir/grand fir overstory, a ninebark/common snowberry/oceanspray midstory, and an elk sedge/pinegrass understory. Ponderosa pine and bunchgrasses dominated the southerly and westerly exposures of the canyons. The canyon bottoms contained small narrow meadows where sedges (*Carex spp.*), rushes (*Juncus spp.*), and Kentucky bluegrass (*Poa pratensis* L.) were dominant. Common chokecherry (*Prunus virginiana* L.), red-osier dogwood (*Cornus stolonifera* Michx.), and mountain maple (*Acer glabrum* Torr.) occurred as widely-scattered individuals along the major drainages. Seeded grasses including orchardgrass (*Dactylis glomerata* L.) and timothy (*Phleum pratense* L.) had been established on old roads and other areas disturbed by logging operations. Vegetation on the forested ridges consisted of a Douglas-fir/ponderosa pine overstory, an ninebark/common snowberry midstory, and an elk sedge/pinegrass understory.

The soils on the ridgetops and droughty exposures were shallow, extremely stony to very cobbly, loams and silt-loams of the Anatone-Bocker complex (Dysterhuis and High 1985, Bryant 1993). Soils on the mesic exposures was probably a Klicker stony silt loam.

The climate was continental with low precipitation, warm to hot summers and cold, dry winters. Most of the precipitation occurred as winter snow and spring rain. The amount and timing of late summer and fall rain was unpredictable but, could occur in sufficient amounts to promote substantial regrowth in perennial grasses. Annual precipitation totals for 1993 and 1994 at Starkey Experimental Forest and Range, less than 15 km away from both study sites, were 59.7 cm and 50.7 cm, respectively. The ten year average (1986 to 1995) for annual precipitation at Starkey Experimental Forest and Range was 54.8 cm (Unpub. data, on file at Forestry and Range Sciences Laboratory, La Grande, OR).

5.4 Methods

5.4.1 Experimental Design

A split plot layout within randomized complete block design was used. Three blocks containing two whole plots were established along selected ridges and associated drainages within the study area. These three blocks represented three different locations within the study area: (1) two ridges and associated drainages near Tybow Canyon, (2) two ridges and associated drainages near McCarty Spring, and (3) two ridges and associated drainages near Cabbage Spring. All the whole plots were dispersed well enough over the study area that interactions between plots were assumed to be minimized.

Each whole plot was 240 m by 800 m in size. Each whole plot was established with the long axis oriented parallel to drainage direction. Whole plots were divided into three similar-sized subplots representing the three dominant vegetation types present within the whole plots:

- 1) Open ridgetop grassland dominated by bluebunch wheatgrass, Idaho fescue, and Sandberg bluegrass.
- 2) Forest/grassland ecotone containing a ponderosa pine overstory and an Idaho fescue/elk sedge/bluebunch wheatgrass understory.
- 3) Forested stringer drainage with a Douglas-fir/grand fir overstory, a ninebark/common snowberry/oceanspray midstory, and an elk sedge/pinegrass understory.

The ecotone and stringer subplots were further divided into areas with forest canopy (i.e., under the canopy of trees greater than 25 cm d.b.h.) and areas without forest canopy.

5.4.2 Treatment Design

Whole plots received two treatments: (1) sheep grazing during the boot phenological stage of bluebunch wheatgrass, and (2) exclusion of sheep grazing. The remaining portion of the McCarty Spring sheep allotment was grazed as normal for the remainder of the grazing season allocated under the allotment management plan. The sheep grazing treatment was randomly assigned to one of the two whole plots in each block. The grazing exclusion treatment was assigned to the remaining whole plot in each block.

Within the whole plots assigned the grazing treatment, sheep grazing was applied during the boot stage of bluebunch wheatgrass until approximately 50% utilization was reached on at least one of the three dominant, graminoid forage species within the whole plots: 1) bluebunch wheatgrass, 2) Idaho fescue and, 3) elk sedge. Electric fencing was used to confine the sheep within the grazed plots during treatment application and to exclude the sheep from the plots after treatment application was completed. The whole plots assigned to the grazing exclusion treatment were not grazed by sheep but big game utilization was not excluded.

The experiment was conducted for two years (i.e., 1993 and 1994). However, to simulate the grazing effect on forage quality under a rest-rotation grazing system, the treatment assignment within each block was reversed during the second year. Whole plots grazed by sheep during the first year were rested or excluded from sheep grazing during the second year.

A problem developed during the first year of treatment application. Almost immediately after the grazing treatments had been applied to all three blocks, the sheep were accidentally allowed into the grazing exclusion whole plot (Plot 1) of the McCarty Spring Block (Block 2). The resulting forage utilization in this whole plot was great enough to prevent it from being used as a grazing exclusion whole plot for Block 2. To salvage the situation, we planned to treat Plot 1 of Block 2 as a grazing treatment whole plot in the statistical

analysis, thus resulting in two grazing treatment whole plots for Block 2 during 1993. In 1994, both whole plots in Block 2 received the grazing exclusion treatment.

5.4.3 Response Design

The percent forage utilization and the number of standing reproductive culms/plant was assessed within each plot immediately following treatment application. Five 150 m pace transects were randomly located within each of the three vegetation types (i.e., subplots) of each whole plot. Forage utilization was estimated at six sampling points located at 25 m intervals along each transect. At each of these sampling points a 0.5 m² quadrat was positioned and the forage utilization was estimated using the ocular estimate-by-plot method (Pechanec and Pickford 1937). In the ridgetop vegetation type of each whole plot, a total of 30 quadrats were sampled for utilization of bluebunch wheatgrass and Idaho fescue. In the forest-grassland ecotone, utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge was estimated in 60 quadrats where at each sampling point per transect, a quadrat was read under the canopy of a nearest neighbor tree of greater than 25 cm d.b.h. and an another quadrat was read in the nearest neighbor canopy opening. In the stringer vegetation type, 60 quadrats were read for utilization of elk sedge using the same methodology as described above for the forest-grassland ecotone species.

The number of standing reproductive culms/plant were measured for bluebunch wheatgrass and Idaho fescue in the ridgetop and ecotone vegetation types using the same quadrats used for utilization sampling. Within each quadrat, the number of standing reproductive culms per species were counted and the total for each species was divided by the number of plants of that species.

During early November, when elk were expected to arrive on the study area, and during early March, when elk were expected to leave the study area, forage quality samples were collected along five randomly located, 150 m transects within each subplot of the whole plots. As discussed below, these transects were also used to assess forage utilization by elk under the same methodology described above for sheep utilization (see chapter 6). Two of the six sampling points per transect were randomly selected for collection of forage quality subsamples. At the selected sampling points, bluebunch wheatgrass, Idaho fescue or elk sedge plants within the 0.5 m² quadrat were clipped to a 2.5 cm stubble height and the harvested material was placed in separate paper bags corresponding to species and location relative to the forest canopy. A total of ten forage quality subsamples were placed into one sample bag each for bluebunch wheatgrass and Idaho fescue in the ridgetop vegetation types. Ten subsamples were collected both under the canopy and in the open for bluebunch wheatgrass, Idaho fescue, and elk sedge in the forest-grassland ecotone (i.e., total of 20 subsamples and 2 sample bags per species). Twenty subsamples of elk sedge, 10 subsamples under the forest canopy and 10 subsamples in the open, were collected in the stringer vegetation type.

The forage samples were oven dried at 50° C until a constant dry weight (± 0.01 grams) was reached. The dried samples were then ground to pass through a 1 mm mesh screen. Ground samples were stored in air-tight bags until laboratory analysis could be performed.

The forage samples were analyzed to determine the percent crude protein, percent *in vitro* dry matter digestibility, and dry matter yield per species for each vegetation type or vegetation type/canopy location during early November and in late March. The percent crude protein in each sample was determined in duplicate using the Kjeldahl method as described by the Association of Official Analytical Chemists (AOAC 1980).

The percent *in vitro* dry matter digestibility in each sample was determined in triplicate using the techniques described by Tilley and Terry (1963). As mentioned in chapter 3, the findings by Campa et al. (1984) suggested *in vitro* digestibility analysis using rumen inoculum from wild elk would provide results more comparable to *in vivo* digestibility by wild elk than would *in vitro* digestibility analysis using rumen inoculum from livestock. However, distance from adequate laboratory facilities made it logistically impossible to utilize rumen inoculum from wild elk in the present study. The rumen inoculum used was a composite sample collected from two fistulated Hereford steers maintained on meadow hay.

The dry matter yield (kg/ha) from each plot was calculated based on the corrected dry weight of the sample from each plot. Two subsamples from each sample were oven dried at 100° C until 100% dry matter was reached. The percent dry matter of each sample was then calculated based on the average difference between the initial and final weights of the two subsamples per sample. The percent dry matter value for each sample was used to correct the original sample weight to a 100% dry matter basis.

Crude protein, *in vitro* dry matter digestibility, and dry matter yield of each species per vegetation type were compared between treatments, years, sampling period, location relative to the forest canopy using General Linear Model (GLM) procedures (SAS 1988). Treatment and sampling period were analyzed as fixed effects, and year and location relative to canopy were analyzed as random effects in the GLM model. A separate analysis was conducted for each species/vegetation type/canopy location combination.

Only data from Block 1 and Block 3 were used in the statistical analysis. Because of the unfortunate treatment assignment in Block 2 (i.e., discussed in the Treatment Design section of this chapter), treatment effects in Block 2 were automatically confounded with year effect. Initially we planned to develop of a correction factor for year effect from Block 1 and Block 3 and use this correction factor when analyzing treatment effects in Block 2. Later, we concluded use of the year effect correction factor in the analysis of treatment effects within Block 2 required reliance on too many assumptions to be a viable procedure. Consequently, only data from Block 1 and Block 3 were used in the statistical analysis of treatment effects or treatment-related interactions.

5.5 Results

During 1993, a slight amount of utilization of bluebunch wheatgrass (0.9 to 1.6%), Idaho fescue (0.1 to 0.9%), and elk sedge (1.8 to 3.1%) occurred in the grazing exclusion treatment whole plots of both Block 1 and Block 3 (Table 5.1, 5.3, and 5.5). A small herd of approximately 9 adult cow elk was occupying the study area during the late spring of 1993. Field observations made prior to treatment application in 1993 indicated these elk utilized forage from all the treatment whole plots. We assumed this slight amount of utilization in the grazing exclusion plots would not confound the statistical analysis of treatment effects.

5.5.1 Bluebunch Wheatgrass

Utilization of bluebunch wheatgrass under the late spring sheep grazing treatment was generally less in 1993 than in 1994 (Table 5.1). The sheep used in the study during 1993 exhibited an agitated behavior, especially when confined within the grazing plots. During the cool morning hours, these sheep tended to trail back and forth from one end of the ridgetop grassland vegetation type to the other and only rarely stopping to graze for short periods of time. Very few of these sheep ventured out of the grassland vegetation type into the ecotone and stringer vegetation types. During the warmer mid day hours, these sheep bedded or stood under the canopy of large trees located adjacent to the ridgetop grassland vegetation type.

Since we were attempting to condition the forage within a narrow phenological window (i.e., the boot stage which generally lasted approximately 9 to 10 days), each grazing treatment plot could be grazed for only three days before the sheep had to be moved on to the next plot. The agitated behavior of the sheep used in 1993 limited their effectiveness as forage conditioning agents and this coupled with the short grazing period prevented us from reaching our target utilization level of 50% for bluebunch wheatgrass, Idaho fescue, or elk sedge. Sheep utilization in 1993 was highest in the grassland vegetation type (Table 5.1) and a substantial amount of trampling of bluebunch wheatgrass was observed in this vegetation type as well.

The sheep used in 1994 exhibited a more relaxed behavior than those used in 1993. The target utilization level was easily reached within the allotted three days per plot. Unlike 1993, the sheep used in 1994 occupied all three vegetation types within each grazing treatment plot. Utilization of bluebunch wheatgrass was highest in the grassland vegetation type and in the forest canopy openings of the ecotone vegetation type (Table 5.1). Utilization of bluebunch wheatgrass was significantly higher in the grassland vegetation type ($P=0.0084$) and in the open ($P=0.0056$) and forested areas ($P=0.0012$) of the ecotone vegetation type of the grazing treatment plots than in the grazing exclusion treatment plots.

In 1993, the production of reproductive culms by bluebunch wheatgrass plants appeared to be greater in the ridge grassland vegetation type ($P=0.1239$) and was greater in open areas of the ecotone vegetation type ($P=0.0005$) of both the grazing and grazing exclusion plots than in 1994 (Table 5.1). The spring of 1993 had

Table 5.1 Sheep utilization and reproductive culms/plant for bluebunch wheatgrass in grassland and ecotone vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Year	Sheep Use (%)	Sheep Use P-Value ²	Reprod. Culms/Plant (June) ³	Culms P-Value (June)	Reprod. Culms/Plant (Nov.)	Culms P-Value (Nov.)
Grassland	Open	Ungrazed	1993	1.6 (2.2745) ⁴	0.1053	6.8 (2.7367)	0.3425	2.9 (0.9973)	0.5961
		Grazed	1993	12.3 (3.6864)		3.9 (1.6676)		2.3 (0.9682)	
		Ungrazed	1994	0.0 (0.0000)	0.0084	2.8 (0.6058)	0.2453	1.1 (0.0183)	0.8813
		Grazed	1994	56.0 (7.3115)		1.4 (1.0528)		1.2 (1.2448)	
Ecotone	Open	Ungrazed	1993	0.9 (1.2256)	0.1171	2.9 (0.5639)	0.7417	2.3 (2.0578)	0.4713
		Grazed	1993	9.0 (4.1484)		2.7 (0.0567)		1.0 (0.5097)	
		Ungrazed	1994	0.0 (0.0000)	0.0056	1.2 (0.4114)	0.2562	0.2 (0.0948)	0.6609
		Grazed	1994	53.5 (5.6851)		0.4 (0.1776)		0.2 (0.0812)	

Table 5.1 Continued

Ecotone	Cover	Ungrazed	1993	1.4 (1.9917)	0.5890	1.0 (0.1851)	0.1000	0.5 (0.0442)	0.7739
		Grazed	1993	4.30 (6.0575)		0.20 (0.3227)		0.4 (0.4616)	
		Ungrazed	1994	0.0 (0.0000)	0.0012	1.3 (1.6263)	0.5332	0.3 (0.4667)	0.7031
		Grazed	1994	40.3 (2.0082)		0.3 (0.3748)		0.2 (0.0865)	

¹Open areas are designated "Open" and areas under the ecotone forest canopy are designated "Cover".

²P-values apply to vegetation type/canopy/year combinations.

³Samples collected immediately following treatment application are designated "June" and early winter samples are designated "Nov.".

⁴Standard deviations are enclosed within parentheses below the means.

higher precipitation than the spring of 1994, which may have accounted for the higher culm production in 1993.

During June of both 1993 and 1994, no significant differences in the number of reproductive culms/bluebunch wheatgrass plant were detected between the grazed and ungrazed plots (Table 5.1). However, a nonsignificant trend towards less culms/plant in the grazed plots appeared to exist. During the time period of June to November of both 1993 and 1994, the number of culms/plant generally seemed to decrease, due to weathering and perhaps big game herbivory, in both the ungrazed and grazed plots. The trend observed in June towards less culms/plant in the grazed plots apparently disappeared by November suggesting a greater loss of culms/plant in the ungrazed plots between June and November.

The forage quality of bluebunch wheatgrass seemed to exhibit a more positive reaction to the late spring sheep grazing treatment than the forage quality of Idaho fescue or elk sedge. Percent crude protein in bluebunch wheatgrass forage appeared to be more responsive to the grazing treatment than percent *in vitro* dry matter digestibility or dry matter yield (Table 5.2).

There was evidence bluebunch wheatgrass samples collected in November from the grassland vegetation type within grazing treatment whole plots were higher in crude protein than November samples from the grazing exclusion treatment ($P=0.0908$). Bluebunch wheatgrass from the forest canopy openings in the ecotone vegetation type of grazing treatment whole plots exhibited higher crude protein in both November ($P=0.0205$) and March ($P=0.0313$) than in open areas of the ecotone vegetation type where sheep grazing had been excluded. The percent crude protein of bluebunch wheatgrass within the ecotone vegetation type of both the grazing and grazing exclusion treatment whole plots increased between the November sampling period and the March sampling periods ($P=0.0126$). Percent crude protein was greater in the grassland ($P=0.0124$) and ecotone ($P=0.0032$) vegetation types of both the grazed and ungrazed whole plots during 1994 compared to 1993.

Late spring sheep grazing appeared to produce some improvement in percent *in vitro* dry matter digestibility of bluebunch wheatgrass compared to the grazing exclusion treatment, especially in the grassland vegetation type (Table 5.2). The percent *in vitro* dry matter digestibility of bluebunch wheatgrass in the grassland ($P=0.1229$) and ecotone ($P=0.1131$) vegetation types within both the grazing and grazing exclusion treatment whole plots tended to remain fairly stable between the November and March sampling periods. In the grassland vegetation type of both grazed and ungrazed whole plots, *in vitro* dry matter digestibility was higher ($P=0.0029$) in 1994 than in 1993.

Table 5.2 Forage quality of bluebunch wheatgrass in different vegetation type/canopy combinations within grazed and ungrazed whole plots.

Vegetation Type	Treatment/ Forest Canopy ¹	Sampling Period/Year ²	Crude Protein (%)	CP P-Value ³	IVDMD (%)	IVDMD P-Value	Dry Matter (kg/ha)	DM P-value
Grassland	Ungrazed/Open	Nov/1993	2.54 (0.1344)	0.0908	36.5 (1.1445)	0.0132	184.2 (20.1313)	0.2492
	Grazed/Open		3.45 (0.5162)		39.8 (1.7819)		158.8 (117.2029)	
	Ungrazed/Open	Nov/1994	3.35 (0.4172)		40.7 (2.4254)		290.4 (94.4624)	
	Grazed/Open		4.31 (0.1414)		46.3 (2.4254)		120.3 (10.9955)	
Grassland	Ungrazed/Open	March/1994	2.84 (0.1768)	0.2014	36.4 (0.8980)	0.1014	242.8 (34.2523)	0.1298
	Grazed/Open		3.29 (0.7283)		37.3 (3.3588)		173.3 (110.6976)	
	Ungrazed/Open	March/1995	4.14 (0.4596)		37.9 (1.0466)		290.0 (82.5335)	
	Grazed/Open		5.76 (0.8061)		45.5 (0.3606)		87.6 (10.4157)	

Table 5.2 Continued

Ecotone	Ungrazed/Open	Nov/1993	3.13 (0.1344)	0.0205	38.5 (1.2799)	0.0675	145.0 (84.4144)	0.5087
	Grazed/Open		3.80 (0.7707)		40.6 (5.7629)		130.7 (45.8630)	
	Ungrazed/Open	Nov/1994	3.23 (0.3536)		38.0 (0.7000)		100.4 (101.4698)	
	Grazed/Open		4.89 (0.3323)		45.6 (2.0506)		81.8 (9.9773)	
Ecotone	Ungrazed/Open	March/1994	3.17 (0.6788)	0.0313	36.7 (3.5638)	0.7922	173.2 (114.0280)	0.5868
	Grazed/Open		3.68 (0.1697)		38.2 (0.5091)		127.7 (83.1416)	
	Ungrazed/Open	March/1995	3.97 (0.3041)		37.9 (0.6364)		64.2 (52.2269)	
	Grazed/Open		5.34 (0.1414)		37.3 (2.9204)		53.1 (25.3286)	

Table 5.2 Continued

Ecotone	Ungrazed/Cover	Nov/1993	2.90 (0.1061)	0.2477	37.1 (0.8415)	0.1091	43.3 (6.4559)	0.4914
	Grazed/Cover		3.68 (0.3536)		39.9 (1.0324)		59.4 (15.1533)	
	Ungrazed/Cover	Nov/1994	3.10 (0.6930)		39.1 (3.2456)		25.2 (33.0572)	
	Grazed/Cover		3.40 (0.1556)		41.2 (0.5091)		37.5 (12.3178)	
Ecotone	Ungrazed/Cover	March/1994	3.19 (0.2546)	0.1980	37.7 (1.4496)	0.2143	65.8 (0.3677)	0.4093
	Grazed/Cover		4.03 (0.4738)		40.9 (0.8061)		39.5 (54.2351)	
	Ungrazed/Cover	March/1995	3.87 (0.2687)		39.5 (4.0234)		21.2 (3.2810)	
	Grazed/Cover		4.59 (0.5515)		42.1 (2.8709)		12.7 (6.8307)	

¹The grazing whole plot treatment is designate "Grazed" and the grazing exclusion treatment is designated "Ungrazed". The absence of forest canopy is designated "Open" and the presence of forest canopy is designated "Cover".

²Samples collected in early November are designated "Nov" and samples collected in March are designated "March".

³P-values apply within vegetation type/canopy/sampling period combinations.

Dry matter yield of bluebunch wheatgrass from the grassland vegetation type of the grazing treatment whole plots was less ($P=0.0457$) than from the ungrazed grassland vegetation type. No statistical differences in dry matter yield ($P=0.4025$) were detected between the ecotone vegetation types of the grazed and ungrazed whole plots. Dry matter yield of bluebunch wheatgrass from the forest canopy openings in the ecotone vegetation type was greater ($P=0.0008$) than under the ecotone forest canopy for both the grazed and ungrazed whole plots (Table 5.2).

5.5.2 Idaho Fescue

Similar to sheep utilization of bluebunch wheatgrass, utilization of Idaho fescue by sheep was highest during 1994 (Table 5.3). Sheep utilization of Idaho fescue was highest in the grassland vegetation type. Although not significant, the production of reproductive culms by Idaho fescue in 1993 appeared to be higher in the grassland vegetation type ($P=0.0667$), and both in open areas ($P=0.1596$) and areas under forest canopy in the ecotone vegetation type ($P=0.1593$) compared to 1994 (Table 5.3). As with bluebunch wheatgrass, the apparently high reproductive culm production in 1993 may have been related to differences in precipitation between 1993 and 1994. Similar to the results from bluebunch wheatgrass, a nonsignificant trend towards lower numbers of reproductive culms/Idaho fescue plant in the grazed whole plots compared to the ungrazed whole plots appeared to exist in June samples. The number of culms/plant tended to decrease between June and November in both the grazed and ungrazed whole plots.

Late spring sheep grazing produced significant differences in the percent crude protein of Idaho fescue in both the March samples from grassland vegetation type ($P=0.0210$) and the November samples from the forest canopy openings within the ecotone vegetation type ($P=0.0307$) of grazing treatment whole plots compared to samples from grazing exclusion treatment whole plots (Table 5.4).

Table 5.3 Sheep utilization and reproductive culms/plant for Idaho fescue in grassland and ecotone vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Year	Sheep Use (%)	Sheep Use P-Value ²	Reprod. Culms/Plant (June) ³	Culms P-Value (June)	Reprod. Culms/Plant (Nov.)	Culms P-Value (Nov.)
Grassland	Open	Ungrazed	1993	0.1 (0.2003)	0.0059	4.3 (0.7573)	0.2624	5.3 (2.4459)	0.3990
		Grazed	1993	10.5 (1.1102)		3.5 (0.2011)		2.9 (2.0826)	
		Ungrazed	1994	0.0 (0.0000)	0.0157	1.8 (0.4561)	0.5233	0.8 (0.4410)	0.1537
		Grazed	1994	52.5 (7.2422)		1.1 (1.2093)		0.1 (0.0316)	
Ecotone	Open	Ungrazed	1993	0.6 (0.8132)	0.1490	3.3 (0.6946)	0.8499	3.7 (1.3877)	0.2473
		Grazed	1993	11.3 (0.0665)		3.7 (2.5454)		1.9 (0.5930)	
		Ungrazed	1994	0.0 (0.0000)	0.0332	1.7 (0.3278)	0.1403	0.7 (0.3750)	0.1454
		Grazed	1994	30.9 (8.1694)		0.6 (0.3012)		0.0 (0.0069)	

Table 5.3 Continued

Ecotone	Cover	Ungrazed	1993	0.9 (1.1644)	0.0929	3.9 (1.1091)	0.5500	2.1 (0.0153)	0.1385
		Grazed	1993	4.7 (1.3503)		3.2 (0.8282)		1.2 (0.5407)	
		Ungrazed	1994	0.0 (0.0000)	0.1287	2.0 (1.1230)	0.3839	1.6 (0.9654)	0.6497
		Grazed	1994	33.4 (18.8397)		1.1 (0.3405)		1.2 (0.5485)	

¹Open areas are designated "Open" and areas under the ecotone forest canopy are designated "Cover".

²P-values apply to vegetation type/canopy/year combinations.

³Samples collected immediately following treatment application are designated "June" and early winter samples are designated "(Nov.)".

⁴Standard deviations are enclosed within parentheses below the means.

Table 5.4 Forage quality of Idaho fescue in different vegetation type/canopy combinations within grazed and ungrazed whole plots.

Vegetation Type	Treatment/Forest Canopy ¹	Sampling Period/Year ²	Crude Protein (%)	CP P-Value ³	IVDMD (%)	IVDMD P-Value	Dry Matter (kg/ha)	DM P-Value
Grassland	Ungrazed/Open	Nov/1993	4.06 (0.8980)	0.1646	44.5 (3.1113)	0.2889	131.7 (49.0237)	0.9759
	Grazed/Open		5.10 (0.9687)		47.3 (5.0770)		164.0 (33.3330)	
	Ungrazed/Open	Nov/1994	5.31 (0.2404)		45.6 (4.0659)		129.3 (52.3471)	
	Grazed/Open		6.69 (0.1414)		51.0 (1.2728)		94.2 (24.4518)	
Grassland	Ungrazed/Open	March/1994	4.55 (0.3748)	0.0210	43.2 (1.4637)	0.8827	128.3 (43.5224)	0.4482
	Grazed/Open		4.58 (0.0071)		41.4 (0.9405)		130.2 (81.7840)	
	Ungrazed/Open	March/1995	5.71 (0.0424)		41.6 (3.5426)		155.7 (4.2709)	
	Grazed/Open		8.25 (0.4313)		43.9 (1.6829)		73.5 (33.0785)	

Table 5.4 Continued

Ecotone	Ungrazed/Open	Nov/1993	4.20 (0.0354)	0.0307	43.6 (3.1820)	0.8745	129.7 (38.2898)	0.7216
	Grazed/Open		4.91 (0.0495)		42.5 (3.6345)		163.5 (65.6478)	
	Ungrazed/Open	Nov/1994	4.92 (0.3465)		44.6 (4.3770)		109.7 (25.9933)	
	Grazed/Open		6.93 (0.5233)		46.7 (1.6405)		51.8 (12.4239)	
Ecotone	Ungrazed/Open	March/1994	4.31 (0.5515)	0.2471	39.6 (2.4607)	0.4719	91.7 (74.7553)	0.8343
	Grazed/Open		4.83 (0.8768)		43.1 (0.2687)		90.1 (70.1238)	
	Ungrazed/Open	March/1995	5.83 (0.0283)		41.4 (1.4566)		108.3 (15.7119)	
	Grazed/Open		7.33 (0.7920)		40.3 (0.5233)		99.3 (48.8399)	

Table 5.4 Continued

Ecotone	Ungrazed/Cover	Nov/1993	4.19 (0.5374)	0.3709	43.7 (1.0041)	0.5349	208.3 (70.4491)	0.5079
	Grazed/Cover		5.09 (0.2687)		44.1 (1.0182)		131.0 (8.1388)	
	Ungrazed/Cover	Nov/1994	4.82 (0.7849)		46.1 (4.1154)		127.6 (42.9638)	
	Grazed/Cover		5.19 (0.5728)		43.0 (0.6364)		140.5 (1.8385)	
Ecotone	Ungrazed/Cover	March/1994	4.67 (0.4596)	0.2246	41.1 (2.0510)	0.1330	142.6 (56.1160)	0.7723
	Grazed/Cover		4.73 (0.1485)		41.3 (0.0707)		132.6 (20.4425)	
	Ungrazed/Cover	March/1995	5.79 (0.5374)		45.6 (0.2758)		93.0 (20.3576)	
	Grazed/Cover		7.07 (0.2828)		41.8 (0.9899)		85.2 (24.9962)	

¹The grazing whole plot treatment is designated "Grazed" and the grazing exclusion treatment is designated "Ungrazed". The absence of forest canopy is designated "Open" and the presence of forest canopy is designated "Cover".

²Samples collected in early November are designated "Nov" and samples collected in March are designated "March".

³P-Values apply within vegetation type/canopy/sampling period combinations.

No significant canopy effects were observed ($P=0.3925$) between open areas and areas under the forest canopy of the ecotone vegetation type in either the grazed or ungrazed whole plots. During the time period between November and March, the percent crude protein of Idaho fescue remained fairly stable in the grassland vegetation type ($P=0.1802$) but appeared to increase in the ecotone vegetation type ($P=0.0517$) of both the grazing and grazing exclusion treatment plots. Percent crude protein in Idaho fescue was greater in 1994 than in 1993 for samples collected from the grassland ($P=0.0029$) and ecotone ($P=0.0004$) vegetation types within both grazed and ungrazed whole plots.

No statistically significant differences in percent *in vitro* dry matter digestibility of Idaho fescue were detected between the two treatments. The *in vitro* dry matter digestibility of Idaho fescue in the grassland ($P=0.0542$) and ecotone ($P=0.0264$) vegetation types of both the grazed and ungrazed plots appeared to decline between the November and March sampling periods.

Dry matter yield from Idaho fescue in the grassland ($P=0.5236$) and ecotone ($P=0.3653$) vegetation types was similar between grazed and ungrazed plots. Dry matter yield in the ecotone vegetation type appeared to be greater ($P=0.0547$) in 1993 than in 1994 for both the grazing and grazing exclusion treatments.

5.5.3 Elk Sedge

Sheep utilization of elk sedge in the grazed plots was generally higher in 1994 than in 1993 (Table 5.5). Elk sedge in the stringer vegetation type of the grazed plots seemed to be more uniformly utilized by sheep in 1994 than in 1993 both in the canopy openings ($P=0.0370$) and under the forest canopy ($P=0.0865$).

Elk sedge was the least responsive, of the three graminoid species studied, to the spring sheep grazing treatment (Table 5.6). Percent crude protein in elk sedge samples collected in March from the canopy openings of the ecotone vegetation type within ungrazed whole plots was greater ($P=0.0346$) than in samples from the ecotone vegetation type within grazed whole plots. No significant differences between the grazed and ungrazed plots were detected for *in vitro* dry matter digestibility or dry matter yield from elk sedge. However, statistically significant year*treatment interactions were detected for crude protein ($P=0.0494$) and *in vitro* dry matter digestibility ($P=0.0122$) in the ecotone and for crude protein ($P=0.0026$) and *in vitro* dry matter digestibility ($P=0.0017$) in stringer vegetation types. Under the lighter grazing of 1993, there appeared to be a trend towards higher crude protein and *in vitro* dry matter digestibility in elk sedge of the grazed plots compared to the ungrazed plots. Conversely, under the heavier grazing of 1994, the crude

Table 5.5 Sheep utilization of elk sedge in ecotone and stringer vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Year	Sheep Use (%)	Sheep Use P-Value ²
Ecotone	No	Ungrazed	1993	1.8 (2.4749) ³	0.3163
		Grazed	1993	17.9 (17.0413)	
		Ungrazed	1994	0.0 (0.0000)	0.0002
		Grazed	1994	49.9 (1.0583)	
Ecotone	Yes	Ungrazed	1993	1.8 (2.4749)	0.3044
		Grazed	1993	7.4 (5.3033)	
		Ungrazed	1994	0.1 (0.1768)	0.0399
		Grazed	1994	20.1 (5.8218)	
Stringer	No	Ungrazed	1993	3.1 (3.8938)	0.8536
		Grazed	1993	2.4 (2.8379)	
		Ungrazed	1994	0.0 (0.0283)	0.0384
		Grazed	1994	31.4 (8.9732)	

Table 5.5 Continued

Stringer	Yes	Ungrazed	1993	2.3 (2.6634)	0.5335
		Grazed	1993	0.9 (0.4714)	
		Ungrazed	1994	0.0 (0.0283)	0.0557
		Grazed	1994	16.2 (5.6427)	

¹Open areas are designated "Open" and areas under the ecotone and stringer forest canopy are designated "Cover".

²P-value applied to vegetation type/canopy/year combinations.

³Standard deviations are enclosed within parentheses below the means.

Table 5.6 Forage quality of elk sedge in different vegetation type/canopy combinations within grazed and ungrazed whole plots.

Vegetation Type	Treatment/ Forest Canopy ¹	Sampling Period/Year ²	Crude Protein (%)	CP P-Value ³	IVDMD (%)	IVDMD P-Value	Dry Matter (kg/ha)	DM P-Value
Ecotone	Ungrazed/Open	Nov/1993	4.45 (0.0849)	0.7913	51.7 (3.6062)	0.3802	71.5 (51.2016)	0.1358
	Grazed/Open		4.93 (0.0849)		54.1 (3.1891)		45.8 (28.3479)	
	Ungrazed/Open	Nov/1994	4.77 (0.0849)		53.4 (4.9003)		124.8 (33.9836)	
	Grazed/Open		4.44 (0.7566)		49.5 (1.7961)		48.3 (28.6308)	
Ecotone	Ungrazed/Open	March/1994	4.66 (0.5869)	0.5599	54.9 (1.5344)	0.2501	14.6 (9.9207)	0.7093
	Grazed/Open		5.29 (0.3606)		52.1 (2.6304)		55.6 (77.3363)	
	Ungrazed/Open	March/1995	4.99 (0.5940)		51.8 (3.8042)		46.8 (1.4637)	
	Grazed/Open		4.94 (0.3394)		48.2 (0.9687)		43.5 (46.6054)	

Table 5.6 Continued

Ecotone	Ungrazed/Cover	Nov/1993	5.72 (0.7495)	0.9775	55.9 (1.2940)	0.1295	113.2 (56.1584)	0.6464
	Grazed/Cover		5.84 (0.1273)		54.9 (0.3111)		62.3 (12.0703)	
	Ungrazed/Cover	Nov/1994	5.11 (0.0981)		56.7 (1.4001)		154.1 (216.7353)	
	Grazed/Cover		5.01 (0.0778)		51.2 (2.1708)		128.5 (135.1917)	
Ecotone	Ungrazed/Cover	March/1994	5.22 (0.4172)	0.0346	52.9 (0.6788)	0.1733	39.1 (6.7458)	0.5862
	Grazed/Cover		5.25 (0.1697)		53.4 (0.3536)		90.8 (79.6627)	
	Ungrazed/Cover	March/1995	5.62 (0.5869)		52.7 (3.0335)		64.2 (5.0558)	
	Grazed/Cover		4.70 (0.3394)		47.7 (1.6122)		68.9 (44.2083)	

Table 5.6 Continued

Stringer	Ungrazed/Open	Nov/1993	5.50 (0.4525)	0.3173	54.8 (0.6152)	0.4652	105.6 (7.4176)	0.1666
	Grazed/Open		7.49 (0.0071)		56.9 (0.6647)		87.1 (21.3617)	
	Ungrazed/Open	Nov/1994	5.92 (0.4384)		56.5 (2.5173)		180.6 (42.8082)	
	Grazed/Open		5.16 (0.9687)		50.9 (3.9244)		123.2 (23.4901)	
Stringer	Ungrazed/Open	March/1994	5.24 (0.3536)	0.3703	52.0 (0.9900)	0.2234	165.5 (86.2317)	0.4552
	Grazed/Open		6.29 (0.1202)		55.4 (0.6152)		130.4 (6.0811)	
	Ungrazed/Open	March/1995	5.88 (0.1838)		53.1 (1.4001)		121.6 (24.0416)	
	Grazed/Open		5.78 (1.0182)		48.5 (1.4496)		84.7 (3.0830)	

Table 5.6 Continued

Stringer	Ungrazed/Cover	Nov/1993	5.44 (1.1879)	0.3299	54.1 (4.8932)	0.5752	95.1 (57.5443)	0.8681
	Grazed/Cover		7.60 (0.0778)		56.8 (3.3870)		80.7 (45.3538)	
	Ungrazed/Cover	Nov/1994	6.71 (0.0283)		57.8 (0.8344)		129.8 (51.4986)	
	Grazed/Cover		5.83 (0.8839)		52.2 (1.2304)		155.8 (41.5001)	
Stringer	Ungrazed/Cover	March/1994	5.18 (0.7212)	0.7583	52.2 (1.2940)	0.6283	243.2 (68.4197)	0.6635
	Grazed/Cover		6.65 (1.2869)		54.9 (1.1172)		102.5 (57.8272)	
	Ungrazed/Cover	March/1995	6.68 (0.7707)		53.6 (0.8132)		66.7 (10.2106)	
	Grazed/Cover		5.73 (0.8132)		49.0 (3.0688)		175.2 (13.4845)	

¹The grazing whole plot treatment is designated "Grazed" and the grazing exclusion treatment is designated "Ungrazed". The absence of forest canopy is designated "Open" and the presence of forest canopy is designated "Cover".

²Samples collected in early November are designated "Nov" and samples collected in March are designated "March".

³P-Values apply within vegetation type/canopy/sampling period combinations.

protein and *in vitro* dry matter digestibility in elk sedge from the grazed plots appeared to be lower than in the ungrazed plots

5.6 Discussion

5.6.1 Utilization vs. Reproductive Culms

The apparently greater production of reproductive culms by Idaho fescue in 1993 compared to 1994 may have strongly influenced how effectively the sheep grazing treatment manipulated the forage quality of Idaho fescue and possibly bluebunch wheatgrass as well. The sheep grazing treatment in this study was applied during the boot stage of bluebunch wheatgrass. Very few bluebunch wheatgrass inflorescences had emerged and elongated out of the boot while the grazing treatment was being applied. However, the phenology of Idaho fescue in the study plots was approximately 10 to 14 days more advanced than bluebunch wheatgrass. Complete elongation of the reproductive culms had already occurred in many Idaho fescue plants by the time the sheep grazing treatment was applied in 1993. The large numbers of reproductive culms in Idaho fescue plants during 1993 may have interfered with sheep attempting to graze both Idaho fescue and neighboring bluebunch wheatgrass plants. Ganskopp et al. (1992) reported beef cattle feeding on crested wheatgrass (*Agropyron cristatum*) responded negatively to increased numbers of reproductive culms/plant. Since sheep are generally regarded as somewhat more selective feeders than beef cattle (Huston and Pinchak 1991), it is probably reasonable to assume grazing sheep would avoid areas with grass plants bearing large numbers of reproductive culms and this may partially explain the lower utilization levels obtained on bluebunch wheatgrass and Idaho fescue in 1993.

The lower sheep utilization and apparently higher production of reproductive culms may have contributed to a possibly higher content of reproductive culms and inflorescences in the forage quality samples of bluebunch wheatgrass and Idaho fescue. The stubble heights of bluebunch wheatgrass and Idaho fescue plants in treatment whole plots grazed by sheep in 1993 were relatively high (i.e., 20.3 to 25.4 cm and 7.6 to 10.2 cm, respectively). Consequently, the apical meristems probably were not removed from most bluebunch wheatgrass and Idaho fescue plants grazed during 1993. Instead of regrowing by tiller production from axillary buds as did the bluebunch wheatgrass plants in the clipping experiment of chapter 3, the grazed appendages of these bluebunch wheatgrass and Idaho fescue plants probably continued to elongate and the phenology of these grazed plants likely was not substantially delayed compared to ungrazed plants. Consequently, the number of reproductive culms/bluebunch wheatgrass or Idaho fescue plant was probably more similar between grazed and ungrazed whole plots under the level of sheep utilization obtained in 1993 than it would have been if heavier utilization had been obtained. Bryant (1993) reported the crude protein and *in vitro* dry matter digestibility of the reproductive culms and inflorescences of cured bluebunch wheatgrass forage collected in

September were significantly lower ($P < 0.05$) than leaf material. Higher content of reproductive culms in the forage samples may partially account for the significant year effects detected for the forage quality of bluebunch wheatgrass and Idaho fescue in the grassland and ecotone vegetation types.

5.6.2 Utilization vs. Forage Quality Response

Statistically significant treatment*year interactions were observed for *in vitro* dry matter digestibility of bluebunch wheatgrass in the grassland vegetation type (0.0449). A treatment*year interaction appeared to exist for the crude protein of Idaho fescue in the grassland vegetation type ($P = 0.0745$). The greater level of sheep utilization obtained in 1994 than in 1993 may have induced these treatment*year interactions observed in bluebunch wheatgrass and Idaho fescue. The heavier utilization observed in the grazing treatments of 1994 may have removed the apical meristems of grazed bluebunch wheatgrass and Idaho fescue plants in the grassland vegetation type, which may have delayed their phenology enough to substantially improve their winter forage quality compared to plants conditioned under the 1993 grazing treatment.

Elk sedge in the ecotone vegetation type seems to exhibit an opposite response to different levels of spring utilization compared bluebunch wheatgrass and Idaho fescue. The treatment*year interactions discussed previously for elk sedge suggest light spring grazing (i.e., less than 20% utilization) in ecotone vegetation type may improve the winter forage quality of elk sedge. Since almost no utilization was obtained in the stringer vegetation type during 1993, conclusions about the effects of light spring utilization on the forage quality of elk sedge in the stringer vegetation type cannot be made. However, the trend towards decreased crude protein and *in vitro* dry matter digestibility under the heavier grazing of 1994 did extend to elk sedge in the stringer vegetation type.

5.6.3 Conclusions and Recommendations

Based on a case history of the forage management system at the Bridge Creek Wildlife Management Area approximately 48 km west of the present study area, Anderson and Scherzinger (1975:121) predicted moderate, late spring cattle grazing would improve the winter forage quality of bunchgrasses such as bluebunch wheatgrass and Idaho fescue as well as prevent the development of a "wolf plant" aspect in these species. The culm/plant and forage quality responses to the late spring sheep grazing treatment in the present study differ somewhat from the responses predicted by Anderson and Scherzinger (1975) for cattle grazing. Spring sheep grazing did not seem to reduce the number reproductive culm/bunchgrass plant compared to bunchgrasses in ungrazed areas. Forage quality responses to the grazing treatment in the present study were not decisive. It is questionable whether the forage quality improvements obtained in the present study would be large enough to influence winter elk distribution (see chapter 6).

The selective grazing behavior of sheep may limit their effectiveness as forage conditioning agents of bunchgrasses. Normally during spring, sheep diets are composed of a relatively high percentage of forbs and their preference for forbs seems to increase during late spring and early summer (Hanley and Hanley 1982). Sheep used in the grazing treatment of the present study tended to seek out palatable forbs and small, young bunchgrass plants and avoided larger, more mature bunchgrass plants. Because of the less selective grazing habits and their graminoid-dominated late spring diets, cattle may be a better choice for forage conditioning treatments, especially where standing litter has accumulated in the larger bunchgrass plants.

The positive forage quality response obtained from bluebunch wheatgrass following the heavier grazing applied in 1994 suggest livestock grazing during the boot phenological stage can improve the winter forage quality of bluebunch wheatgrass. However, use of cattle rather than sheep as the conditioning agent may have produced a larger and more consistent forage quality response in bluebunch wheatgrass.

Because the phenology of Idaho fescue on the study area tended to be 10 to 14 days earlier than bluebunch wheatgrass, forage conditioning of Idaho fescue with sheep may be more successful if sheep grazing is applied earlier, during the boot stage of Idaho fescue rather than during the boot stage of bluebunch wheatgrass. Applying the sheep grazing treatment earlier, prior to the development of large numbers of reproductive culms in Idaho fescue plants may allow more even and efficient utilization of both Idaho fescue and neighboring bluebunch wheatgrass plants. Earlier grazing may more successfully reduce the number of reproductive culms/plant and improve the winter forage quality of Idaho fescue than did the sheep grazing treatment used in the present study.

The forage conditioning technique described by Anderson and Scherzinger (1975) dealt primarily with cool season bunchgrasses. To our knowledge, there is no published research findings on the winter forage quality response of elk sedge to spring livestock grazing treatments. Although our results were not conclusive, there is some indication light grazing of elk sedge may improve the winter forage quality over elk sedge in ungrazed area.

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Chapter 6

Effect of Late Spring Livestock Grazing
on Forage and Habitat Use Patterns of Wintering Elk

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6. EFFECT OF LATE SPRING LIVESTOCK GRAZING ON FORAGE AND HABITAT USE PATTERNS OF WINTERING ELK

6.1 Abstract

The winter distribution and forage utilization of Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) on a winter range in northeastern Oregon were measured in response to two forage treatments: 1) a late spring livestock grazing treatment intended to improve the winter forage quality of bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith), Idaho fescue (*Festuca idahoensis* Elmer), and elk sedge (*Carex geyeri* Boott), and 2) a livestock exclusion treatment. Winter distribution of elk was assessed using an automated LORAN-based telemetry system. Winter elk distribution patterns and utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge were similar between the grazing and grazing exclusion treatments.

6.2 Introduction

Livestock grazing has been successfully used to manage winter Rocky Mountain elk (*Cervus elaphus nelsoni* Bailey) distribution (Frisina and Morin 1991, Anderson and Scherzinger 1975). Working in northeastern Oregon on a publicly-owned wildlife management area where livestock grazing had previously been prohibited, Anderson and Scherzinger (1975) reported winter elk numbers in the area increased from 320 to 1,191 head under 10 years of rest-rotation cattle grazing. The rest-rotation grazing system used on the area emphasized carefully monitored, late spring cattle grazing to improve winter range quality for big game animals. Increases in the number of elk wintering on the management area were believed to be linked to decreases in standing litter and increases in winter forage quality of bluebunch wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) and Idaho fescue (*Festuca idahoensis* Elmer) following late spring cattle grazing. However, no quantitative data were collected to verify this hypothesis.

Several studies have examined whether late spring defoliation could improve the forage quality of bluebunch wheatgrass (Pitt 1986, Bryant 1993, Westenskow-Wall et al. 1994). There are indications that if defoliation is correctly timed with plant phenology, increases in the nutritional value of cured forage can be obtained. However, it is debatable whether these increases in forage quality are large enough to attract wintering elk and alter their winter distribution.

Our objective was to evaluate the winter forage utilization and winter distribution response of elk to two forage treatments: 1) livestock grazing during the boot phenological stage of bluebunch wheatgrass, and 2) exclusion of livestock grazing. Forage utilization of bluebunch wheatgrass, Idaho fescue and elk sedge (*Carex geyeri* Boott) was estimated during early and late winter following treatment application. Winter elk

distribution was evaluated using a LORAN-based telemetry system tracking 15 adult cow elk captured and radio-collared on the study area.

6.3 Study Area

The 2073 ha study area was located adjacent to Starkey Experimental Forest and Range in the Blue Mountains of northeastern Oregon. The study area occupied the southwestern corner of the McCarty Spring sheep allotment managed by the USDA Forest Service. Sheep grazed the study area from early June until early October. The study area was also situated within with a USDA Forest Service vehicle closure. Use of motor vehicles in the study area during winter and early spring (early December to early April) had been prohibited in the closure area since 1984.

The elevation of the study area extended from 1170 m in the northeastern corner to 1536 m in the southwestern corner. Several nearly parallel drainages crossed the study area flowing in a northeasterly direction. The topography in the northern half of the study area consisted of broad open ridges bordered by shallow, forested stringer drainages. Bluebunch wheatgrass, Idaho fescue, Sandberg bluegrass (*Poa secunda* Presl.), and western yarrow (*Achillea millefolium* L.) were dominant on the open ridges. Ecotone vegetation between the ridges and stringer drainages contained a ponderosa pine (*Pinus ponderosa* Dougl.) overstory with an Idaho fescue/elk sedge/bluebunch wheatgrass understory. Douglas-fir and grand fir (*Abies grandis* [Dougl.] Forbs) were the dominant overstory species in the stringer drainage vegetation. Mallow ninebark (*Physocarpus malvaceous* [Greene] Kuntze), common snowberry (*Symphoricarpos albus* [L.] Blake), and oceanspray (*Holodiscus discolor* [Pursh] Maxim.) were dominant in the midstory and elk sedge and pinegrass (*Calamagrostis rubescens* Buckl.) dominated understory in the stringer drainages. The topography in southern half of the study area consisted of deep canyons and forested ridgetops. Vegetation consisting of a Douglas-fir/grand fir overstory, a ninebark/common snowberry/oceanspray midstory, and an elk sedge/pinegrass understory occurred on the northerly and easterly canyon slopes. Ponderosa pine and bunchgrasses dominated the southerly and westerly exposures of the canyons. Sedges (*Carex spp.*), rushes (*Juncus spp.*), and Kentucky bluegrass (*Poa pratensis* L.) were dominant in the small narrow meadows that occurred in the canyon bottoms. Common chokecherry (*Prunus virginiana* L.), red-osier dogwood (*Cornus stolonifera* Michx.), and mountain maple (*Acer glabrum* Torr.) occurred as scattered plants along the major drainages. Seeded grasses including orchardgrass (*Dactylis glomerata* L.) and timothy (*Phleum pratense* L.) had been established on old roads and other areas disturbed by logging operations. Vegetation on the forested ridges consisted of a Douglas-fir/ponderosa pine overstory, an ninebark/common snowberry midstory, and an elk sedge/pinegrass understory.

Shallow, extremely stony to very cobbly, loam and silt-loam soils of the Anatone-Bocker complex occurred on the ridgetops and droughty southerly exposures (Dysterhuis and High 1985, Bryant 1993). Soils on the mesic exposures were probably a Klicker stony silt loam.

The climate was continental with low precipitation, warm to hot summers and cold, dry winters. Most of the precipitation occurred as winter snow and spring rain. The amount and timing of late summer and fall rain was unpredictable but, could occur in sufficient amounts to promote substantial regrowth in perennial grasses. Annual precipitation totals for 1993 and 1994 at Starkey Experimental Forest and Range, less than 15 km away from both study sites, were 59.7 cm and 50.7 cm, respectively. The ten year average (1986 to 1995) for annual precipitation at Starkey Experimental Forest and Range was 54.8 cm (Unpubl. data, on file at Forestry and Range Sciences Laboratory, La Grande, OR).

6.4 Methods

6.4.1 Experimental Design

A split plot layout within a randomized complete block experimental design was used (see chapter 5). Six whole plots, grouped by location into three blocks of two whole plots each, were established on the southeastern slopes of six, nearly parallel drainages within the study area. All the whole plots were dispersed well enough over the study area that interactions between plots were assumed to be minimized.

Each whole plot was 240 m by 800 m (19 ha) in size and oriented so that its long axis was parallel to drainage direction. The elevation and aspect of each whole plot were similar. The following three dominant vegetation types were present in similar amounts within each whole plot:

- 1) Open ridgetop grassland dominated by bluebunch wheatgrass, Idaho fescue, and Sandberg bluegrass.
- 2) Forest/grassland ecotone containing a ponderosa pine overstory and an Idaho fescue/elk sedge/bluebunch wheatgrass understory.
- 3) Forested stringer drainage with a Douglas-fir/grand fir overstory, a ninebark/common snowberry/oceanspray midstory, and an elk sedge/pinegrass understory.

The boundaries of these three vegetation types were mapped and treated as subplots within each whole plot. The ecotone and stringer vegetation types were further divided into areas with forest canopy (i.e., under the canopy of trees greater than 25 cm d.b.h.) and open areas (i.e., areas without forest canopy).

6.4.2 Treatment Design

One whole plot from within each block was randomly assigned one of two treatments: 1) Grazing by domestic sheep during the boot phenological stage of bluebunch wheatgrass, and 2) exclusion of sheep grazing.

The second whole plot within each block was assigned the remaining treatment. The remaining portion of the McCarty Spring sheep allotment not included in the whole plots was moderately grazed from early June to early October. Electric fencing was used to confine sheep within whole plots receiving the grazing treatment and exclude sheep from the grazing exclusion treatment plots.

In the grazed plots, sheep grazing was applied in early June 1993 and 1994 until approximately 50% utilization was reached on at least one of the three dominant, graminoid forage species within the plots: 1) bluebunch wheatgrass, 2) Idaho fescue and, 3) elk sedge. This target level of utilization was reached for both bluebunch wheatgrass and Idaho fescue after a band of 1000 ewes and lambs had occupied a whole plot for 48 to 72 hours. Under this intensity of grazing, utilization of elk sedge was approximately 30% in the ecotone and stringer vegetation types. After application of the grazing treatments, sheep were excluded from the grazed plots for the remainder of the grazing season with electric fencing. Sheep were excluded from the grazing exclusion treatment plots for the entire grazing season.

Initially, the treatments were intended to be replicated three times (i.e., once per block) during 1993 and the treatment assignment within each block was reversed in 1994 to simulate the effects of a rest-rotation grazing system. However, almost immediately after the grazing treatments had been applied during early June 1993, the sheep were accidentally allowed to graze the grazing exclusion treatment whole plot (Plot 1) within Block 2. Enough utilization occurred in this whole plot to prevent it from being used as a grazing exclusion treatment plot for Block 2. In an attempt of salvage the situation, we planned to treat Plot 1 as a grazing treatment whole plot in the statistical analysis, giving two grazed treatments in Block 2. The following year both Plot 1 and Plot 2 of Block 2 received the grazing exclusion treatment. We intended to develop an year effect from the other two blocks to be used as a correction factor when testing for treatment effects within block 2. Later, we decided too many assumptions were required to make this a viable procedure. Consequently, analysis of treatment effects was conducted only on data from Block 1 and Block 3.

6.4.3 Response Design

The percent utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge was assessed within each plot in early November 1993 and 1994; when wintering elk were first expected to arrive on the study area, and in early March 1994 and 1995; when elk were expected to begin to leave the study area to forage at higher elevations. Five 150 m pace transects were randomly located in each of the three vegetation types within each whole plot. Forage utilization was estimated at six sampling points located at 25 m intervals along each transect. At each of these sampling points a 0.5 m² quadrant was positioned and the forage utilization was estimated using the ocular estimate-by-plot method (Pechanec and Pickford 1937). In the ridgetop grassland vegetation type, a total of 30 quadrats were sampled for utilization of bluebunch wheatgrass and Idaho fescue. In the forest-grassland ecotone vegetation type, utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge as estimated in 60 quadrats where at each sampling point per transect, a quadrat was read under the

canopy of a nearest neighbor tree of greater than 25 cm d.b.h. and another quadrat was read in the nearest neighbor canopy opening. In the stringer vegetation type, 60 quadrats were read for utilization of elk sedge using the same methodology as described above for the forest-grassland ecotone species. To separate forage utilization by sheep from elk utilization, the utilization data from the November and March sampling periods were compared. The increases in forage utilization detected between the November and March sampling periods were attributed to elk utilization. To use these utilization data as a measure of elk response to the forage conditioning treatment, two assumptions had to be made. First, elk and mule deer (*Odocoileus hemionus*) were the only large herbivores on the study area during winter and winter utilization of bluebunch wheatgrass, Idaho fescue and elk sedge within the whole plots by mule deer was negligible. During both winters of the study, there was no evidence (i.e., tracks, fecal material, or direct observation) of any other large herbivore on the study area after late October except elk and mule deer. Using the field techniques described above, mule deer utilization of bluebunch wheatgrass, Idaho fescue, or elk sedge could not be separated from elk utilization for these species. However, there were a very limited number of mule deer present on the study area during both winters of the study. Field observations of these deer suggested their diets were composed primarily of elk sedge, Idaho fescue, ponderosa pine, and shrub browse. Although mule deer utilization of elk sedge and Idaho fescue may have inflated the estimate for elk utilization on these species, almost all the mule deer observed on the study area were at lower elevations than where the study plots were located. The limited amount of forage utilized by mule deer within the plots was assumed to be inconsequential to this study. Second, winter environmental conditions were assumed to stop or greatly retard the growth of bluebunch wheatgrass, Idaho fescue, and elk sedge. However, using increases in forage utilization between the November and March sampling periods as a measure of winter elk utilization may underestimate the actual level of utilization. If plant growth was not completely arrested by winter environmental conditions, growth and elongation of plant appendages could have effectively masked evidence of forage utilization. Field observations suggest that elk utilization of Idaho fescue and perhaps bluebunch wheatgrass, especially in the grazing treatment plots, may have been underestimated because of winter growth in these species.

Occupancy of the whole plots by wintering elk was used as another measure of elk response to the forage conditioning treatment. The locations of individual radio-collared elk within the study area were determined on an hourly basis 24 hr per day from mid January to late March 1994 and from early November 1994 to late March 1995. However, in order to simplify comparisons of elk distribution between winters 1993-94 and 1994-95, only locations collected between mid January to late March of winter 1994-95 were analyzed in the present study. A Long Range Navigation (LORAN)-based telemetry system located at Starkey Experimental Forest and Range was used to track the distribution of 15 adult cow elk on the study area. These 15 elk were captured on the study area during mid January 1994 via a helicopter fitted with net guns.

The accuracy of the LORAN-based telemetry system at Starkey Experimental Forest and Range was somewhat limited by topographic effects. We used procedures similar to those previously used within the big game enclosure at Starkey Experimental Forest and Range (Pers. Comm. Bruce Johnson and Scott Findholt,

Project Leader and Research Wildlife Biologist, Oregon Department of Fish and Wildlife, June 10, 1992) to compensate for these topographic effects and improve the accuracy of the telemetry system. A grid with nodes at 800 m intervals was established over the entire study area. Each node of the grid represented the location of a Global Positioning System (GPS)/LORAN control point. At each of GPS/LORAN control point, a portable LORAN receiver and a portable GPS receiver were used to determine the LORAN-generated coordinates and the GPS-generated coordinates, respectively, for the location of the control point. The GPS data collected in the field was differentially-corrected to an expected accuracy of ± 5 meters from the actual geographic locations. The differences between Loran-generated locations and GPS-generated locations for each control point were used as data for a block kriging analysis used to develop correction factors for Loran-based radio-collar locations within the control point grid.

For the analyses used in this study, each radio-collared elk location was treated as a point sample. It could be argued that the elk locations would be more accurately represented by a confidence interval polygon. For example, if the known error of the telemetry system was ± 50 m north-south and ± 150 m east-west, then a rectangle 100 m by 300 m in size centered over the telemetry location would represent the 100% confidence interval polygon for that location. A 90% confidence interval polygon for the location would be somewhat smaller. However, analyses conducted using telemetry locations from GPS control points within Starkey Experimental Forest and Range suggest, for the purposes of the research being conducted within the big game enclosure at Starkey Experimental Forest and Range, the use of the radio-collar locations as point estimates is probably acceptable. The resources required to develop error polygons from the elk locations used in the present study were not available at the time of this writing. Consequently, the elk location data used in the following analyses were treated as point samples.

The question of whether telemetry location data can be treated as independent samples must also be addressed here. Since elk are gregarious animals that often congregate in large herds of 100 animals or more during winter, it is possible that two or more radio-collared elk may join the same herd and begin traveling and foraging together. The telemetry locations of these two radio-collared elk could not be considered independent samples since the behavior and location of one radio-collared elk may influence the behavior and location of the other radio-collared elk in the herd. For our analysis, we considered telemetry locations from different radio-collared elk to be independent of each other if the locations were greater than 500 m apart or if the locations were less than 500 m apart but the time interval between the locations was greater than 24 hours. Telemetry locations of different elk which were both less than 500 m apart and collected less than 24 hours from each other were excluded from the analysis due to lack of independence. We considered 500 m to be a great enough distance, given the topography and vegetation present on the study area, to minimize behavioral interactions between individual elk. A 24 hr time lag was considered long enough to minimize any interactions between the locations of different radio-collared elk.

To assess canopy closure influences on forage utilization and habitat occupancy by wintering elk, the forest canopy closure was sampled in the ecotone and stringer vegetation types within each whole plot. Canopy

photographs were taken along transects within these two vegetation types using a 35 mm camera equipped with a 100 mm lens and mounted on a leveled tripod. Digital images of each photograph were created using a flat bed scanner. A geographic information system (Idrisi ver. 4.0) was used to calculate the percent of the area of each image represented by forest canopy. The mean percent canopy closure of each ecotone and stringer vegetation type was calculated from the percent area sample data obtained from the photographs.

To evaluate the effects of climatic conditions on forage utilization and habitat occupancy by wintering elk, weather stations were set up within each whole plot to measure the weather severity. A single weather station was located within the ecotone vegetation type near the geographic center of each whole plot. At each weather station; ambient temperature, relative humidity, and global radiation were recorded using hygrothermographs and pyranometers, or electronic dataloggers (Unidata, Starlog Data Logging Systems, Willetton, Australia).

To compare climatic effects within vegetation types, one whole plot per block was randomly selected and a datalogger and a totalizing anemometer was installed near the geographic center of each vegetation type to collect data on ambient temperature, relative humidity, global radiation and mean wind speed. However, due to equipment problems, the totalizing anemometers were only installed in the selected plots of Block 1 and Block 2.

Weather stations were also established at the ends of each whole plot to test for climatic differences due to the elevation increase between the northern and southern ends of the whole plots. Maximum and minimum ambient temperature data from each vegetation type were collected via max/min thermometers installed at both the northern and southern ends of each whole plot (i.e., six max/min thermometers per whole plot). Snow depth and elk sinking depth data were also collected at the max/min thermometer locations. Snow depth was measured both in the open and under the canopy of trees greater than 25 cm d.b.h. using a metal ruler. The sinking depth in snow of an adult cow elk was estimated using a soil penetrometer with an epoxy-cast elk hoof threaded onto the shaft. Unmodified soil penetrometers have previously been effectively used to study snow density and its influences on traveling and foraging ungulates (Lent and Knutson 1971). We assumed an epoxy-cast elk hoof would provide a better simulation of the influences of snow density on the sinking depth of elk than would the standard 6.5 cm² penetrometer cone. The shape and surface area of an ungulates hooves strongly influence its foot-load and its sinking depth in snow (Kelsall 1969, Kelsall and Telfer 1971, Telfer and Kelsall 1979, Parker et al. 1984). The penetrometer used in the present study, was calibrated to simulate the sinking depth of a foraging elk when a specific amount of downward pressure (i.e., as read from the output dial on the penetrometer) was applied on the handle. Since the live weight of the cow elk whose front hoof was used to make the epoxy-cast hoof was unknown, weight data for calibration of the penetrometer to an adult cow elk were obtained from late winter handling records of elk on Starkey Experimental Forest and Range. The mean weight of 157 adult cow elk (i.e., greater than 2 years old) weighed on electronic scales during late March and early April 1993 was 209 kg (Unpublished data, on file at Forestry and Range Sciences Laboratory, La Grande, OR.). Hoof area measurements of the epoxy-cast hoof followed procedures similar to

Telfer and Kelsall (1979), but the actual contact area of the fetlock and dewclaws was calculated. The hoof area of the epoxy-cast hoof was 60.2 cm². The hoof-loading of a 209 kg cow elk with a front hoof area of 60.2 cm² would be 867.9 gm/cm² (Telfer and Kelsall 1979). Since both the depth and density of the snow pack likely influence the sinking depth of an ungulate (Verme 1968, Peek 1971, Parker et al. 1984). To evaluate the influence of differences in snow density as well as snow depth, the sinking depth data was analyzed as a percentage of the depth of the snow pack.

Maximum/minimum ambient temperature and snow depth data were collected at regular intervals throughout winters 1993-94 and 1994-95. Percent sinking depth data was collected only during winter 1994-95.

Forage utilization was compared between treatments, years, sampling periods, and location relative to the forest canopy using General Linear Modeling (GLM) procedures (SAS 1988). Treatment and sampling period were analyzed as fixed effects, and year and location relative to canopy were analyzed as random effects in the GLM model. A separate analysis was conducted for each species/vegetation type/canopy location combination. The plot occupancy response was compared between treatments and years. Treatment and year were analyzed as fixed and random effects, respectively. Maximum/minimum temperature, snow depth, and sinking depth were compared between treatments, vegetation types, and plot ends. Treatment was analyzed as a fixed effect while vegetation type and plot end were analyzed as random effects. Wind speed was compared between vegetation types using a random effects model. Where differences were detected, Fisher's Least Significant Difference (LSD) procedure was used to make multiple comparisons based on a 5% level of significance (SAS 1988, Montgomery 1991).

6.5 Results

6.5.1 Forage Utilization by Elk

No significant differences in elk utilization of bluebunch wheatgrass, Idaho fescue, or elk sedge were detected between the grazed and ungrazed vegetation type/canopy combinations within Block 1 and Block 3 (Tables 6.1, 6.2, and 6.3). As mentioned above, treatment effects within Block 2 could not be analyzed.

Although not significant, elk utilization of bluebunch wheatgrass in the ridge vegetation type and open areas of the ecotone vegetation type within the grazed treatment plots appeared to be generally less than in the same areas of the grazing exclusion treatment plots (Table 6.1). However, data from the grazed plots often indicated negative utilization of bluebunch wheatgrass had occurred. It is likely that winter growth and/or sampling error masked the true level of elk utilization of bluebunch wheatgrass on these plots.

During both winters 1993-94 and 1994-95, elk utilization of Idaho fescue in the ridge vegetation type seemed to be greater in the grazed plots than in the grazing exclusion plots, although these differences were not significant (Table 6.2).

Although not significant, elk utilization of elk sedge appeared to be greater in areas located under the forest canopy of the ecotone vegetation type within the grazing treatment plots than in these same areas within the grazing exclusion treatment plots (Table 6.3). These apparent differences in elk utilization of elk sedge under the forest canopy were greatest during winter 1994-95 when sheep utilization of elk sedge was highest.

6.5.2 Plot Occupancy by Elk

During the winters 1993-94 and 1994-95, a total of 9,586 reliable radio-collar locations were collected from the 15 cow elk captured on the study area during mid January 1994 (Figure 6.1). Similar to the forage utilization results, no significant differences were detected in plot occupancy by elk between the grazing and grazing exclusion treatment plots within Block 1 and Block 3 (Figures 6.2 and 6.3).

However, during mid January to late March of winter 1993-94, the radio-collared elk appeared to exhibit a nonsignificant ($P=0.1341$) tendency towards greater mean occupancy in the grazing treatment plots (3 telemetry locations/plot) compared to the grazing exclusion plots (0.5 telemetry locations/plot) (Table 6.4). A total of eight telemetry locations occurred within the study plots during late winter 1993-94 compared to seven locations during late winter 1994-95 (Tables 6.4 and 6.5). The trend in mean occupancy of grazed (1.5 telemetry locations/plot) and ungrazed (4 telemetry locations/plot) plots was apparently reversed during mid January to late March of winter 1994-95, although no significant treatment effects were detected ($P=0.4379$).

6.5.3 Environmental Differences: Canopy Closure

No statistical differences in forest canopy closure ($P=0.4551$) were detected between the whole plots of Block 1 and Block 3 (Table 6.6). Significant differences in canopy closure were detected between the ecotone and stringer vegetation types ($P=0.0147$). Canopy closure in the stringer vegetation type was greater than in the ecotone vegetation type ($P<0.05$). It is unlikely that elk utilization of different whole plots was influenced by differences in canopy closure. Although, differences in canopy closure possibly could have influenced elk utilization of different vegetation types.

Table 6.1 Elk utilization of bluebunch wheatgrass in grassland and ecotone vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Winter	Elk Utilization (%)	Elk Utilization (P-Value) ²
Grassland	Open	Ungrazed	1993-94	4.7 (6.4606) ³	0.4212
		Grazed	1993-94	-3.2 (8.9873)	
		Ungrazed	1994-95	0.3 (0.3206)	0.4103
		Grazed	1994-95	-6.5 (9.3927)	
Ecotone	Open	Ungrazed	1993-94	5.5 (5.9114)	0.5904
		Grazed	1993-94	2.8 (0.8721)	
		Ungrazed	1994-95	0.4 (0.6128)	0.5383
		Grazed	1994-95	-7.8 (15.7567)	
Ecotone	Cover	Ungrazed	1993-94	1.0 (1.2374)	0.9768
		Grazed	1993-94	1.2 (10.6113)	
		Ungrazed	1994-95	0.6 (0.8862)	0.9910
		Grazed	1994-95	0.5 (18.1679)	

¹Open areas are designated "Open" and areas under the ecotone forest canopy are designated "Cover".

²P-Values apply within vegetation type/canopy/winter combinations.

³Standard deviations are enclosed within parentheses below the means.

Table 6.2 Elk utilization of Idaho fescue in grassland and ecotone vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Winter	Elk Utilization (%)	Elk Utilization P-Value ²
Grassland	Open	Ungrazed	1993-94	3.4 (3.1726) ³	0.5619
		Grazed	1993-94	10.6 (14.4014)	
		Ungrazed	1994-95	8.6 (8.2095)	0.7978
		Grazed	1994-95	13.8 (23.7824)	
Ecotone	Open	Ungrazed	1993-94	0.9 (1.2799)	0.3003
		Grazed	1993-94	6.7 (5.7582)	
		Ungrazed	1994-95	0.3 (0.4855)	0.9487
		Grazed	1994-95	0.2 (2.7789)	
Ecotone	Cover	Ungrazed	1993-94	0.2 (2.6352)	0.8300
		Grazed	1993-94	1.5 (7.3681)	
		Ungrazed	1994-95	5.7 (1.6452)	0.7516
		Grazed	1994-95	-0.4 (23.6409)	

¹Open areas are designated "Open" and areas under ecotone forest canopy are designated "Cover".

²P-values apply within vegetation type/canopy/winter combinations.

³Standard deviations are enclosed within parentheses below the means.

Table 6.3 Elk utilization of elk sedge in ecotone and stringer vegetation types.

Vegetation Type	Forest Canopy ¹	Treatment	Winter	Elk Utilization (%)	Elk Utilization P-Value ²
Ecotone	Open	Ungrazed	1993-94	5.4 (0.7778)	0.3503
		Grazed	1993-94	-5.0 (12.1740)	
		Ungrazed	1994-95	4.4 (7.2078)	0.4276
		Grazed	1994-95	10.0 (3.5120)	
Ecotone	Cover	Ungrazed	1993-94	14.8 (11.5376)	0.7021
		Grazed	1993-94	9.9 (11.0450)	
		Ungrazed	1994-95	22.6 (14.1285)	0.2295
		Grazed	1994-95	3.9 (6.2390)	
Stringer	Open	Ungrazed	1993-94	-1.3 (3.1396)	0.4081
		Grazed	1993-94	3.9 (6.3757)	
		Ungrazed	1994-95	1.9 (3.1584)	0.3452
		Grazed	1994-95	10.3 (9.0675)	

Table 6.3 Continued

Stringer	Cover	Ungrazed	1993-94	1.9 (4.6834)	0.3488
		Grazed	1993-94	13.6 (12.6996)	
		Ungrazed	1994-95	-5.6 (8.4994)	0.4945
		Grazed	1994-95	0.9 (7.1818)	

¹Open areas are designated "Open" and areas under the ecotone and stringer forest canopy are designated "Cover".

²P-values apply within vegetation type/canopy/winter combinations.

³Standard deviations are enclosed within parentheses below the means.

6.5.4 Environmental Differences: Climate

Problems with calibration of the data logger data to data from standardization equipment have prevented formal analysis of climatic differences between whole plots or vegetation types using datalogger data collected in winters 1993-94 and 1994-95. However, informal examination of data collected during winter 1992-93 (i.e., prior to treatment application), at the ecotone weather stations of each whole plot using hygrothermographs, suggests that the daily averages for ambient temperature and relative humidity were similar between whole plots.

Maximum ambient temperatures collected via max/min thermometers were similar between ungrazed and ungrazed whole plots within Block 1 and Block 3 during winters 1993-94 and 1994-95 ($P=0.6873$) (Table 6.7). Although not significantly different ($P=0.1605$), maximum ambient temperatures in the grassland vegetation type appeared to be greater than maximum temperatures in the stringer vegetation type. Minimum ambient temperatures were not significantly different between treatment whole plots ($P=0.8613$) or between vegetation types within whole plots ($P=0.6106$) during winters 1993-94 and 1994-95 (Table 6.7). Differences in elevation between the northern and southern ends of the whole plots did not significantly effect either maximum ($P=0.4532$) or minimum ($P=0.3746$) ambient temperatures.

Table 6.4 Telemetry elk locations within the whole plots during winter 1993-94.

Block-Plot Number	Elk ID Number	Date	Time	UTM Coordinates Zone 11N		Ambient Temperature (C°) ¹
				Easting (m)	Northing (m)	
1-1	124	1-20-94	0842	384165	5006165	-5.8
	124	1-20-94	1039	384202	5006157	0.6
1-2	144	2-2-94	1502	384617	5005929	5.4
3-1	183	3-16-94	1234	386928	5004840	3.8
	183	3-16-94	1427	386959	5004829	7.0
	183	3-16-94	1524	386905	5004819	5.4
	183	3-16-94	1623	386954	5004845	5.4

¹Ambient temperature data obtained via a temperature sensor on the exterior side of the radio-collar. These data may include slight errors due to the body heat of the elk and solar heating of the collar.

Table 6.5 Telemetry elk locations within the whole plots during winter 1994-95.

Block-Plot Number	Elk ID Number	Date	Time	UTM Coordinates Zone 11		Ambient Temperature (Deg. C)
				Easting (m)	Northing (m)	
1-1	163	2-27-95	1836	383821	5005999	-2.6
	163	2-28-95	0505	383950	5006214	-5.8
	163	2-28-95	0639	383866	5005986	-7.4
	180	2-27-95	2005	384226	5006462	0.6
	180	2-28-95	0644	384040	5006015	-9.0
1-2	180	2-28-95	1914	384682	5006078	-4.2
3-2	180	2-6-95	1741	387511	5005096	7.0
	180	2-7-95	1719	387688	5005210	2.2

¹Ambient temperature data obtained via a temperature sensor on the exterior side of the radio-collar. These data may include slight errors due to the body heat of the elk and solar heating of the radio-collar.

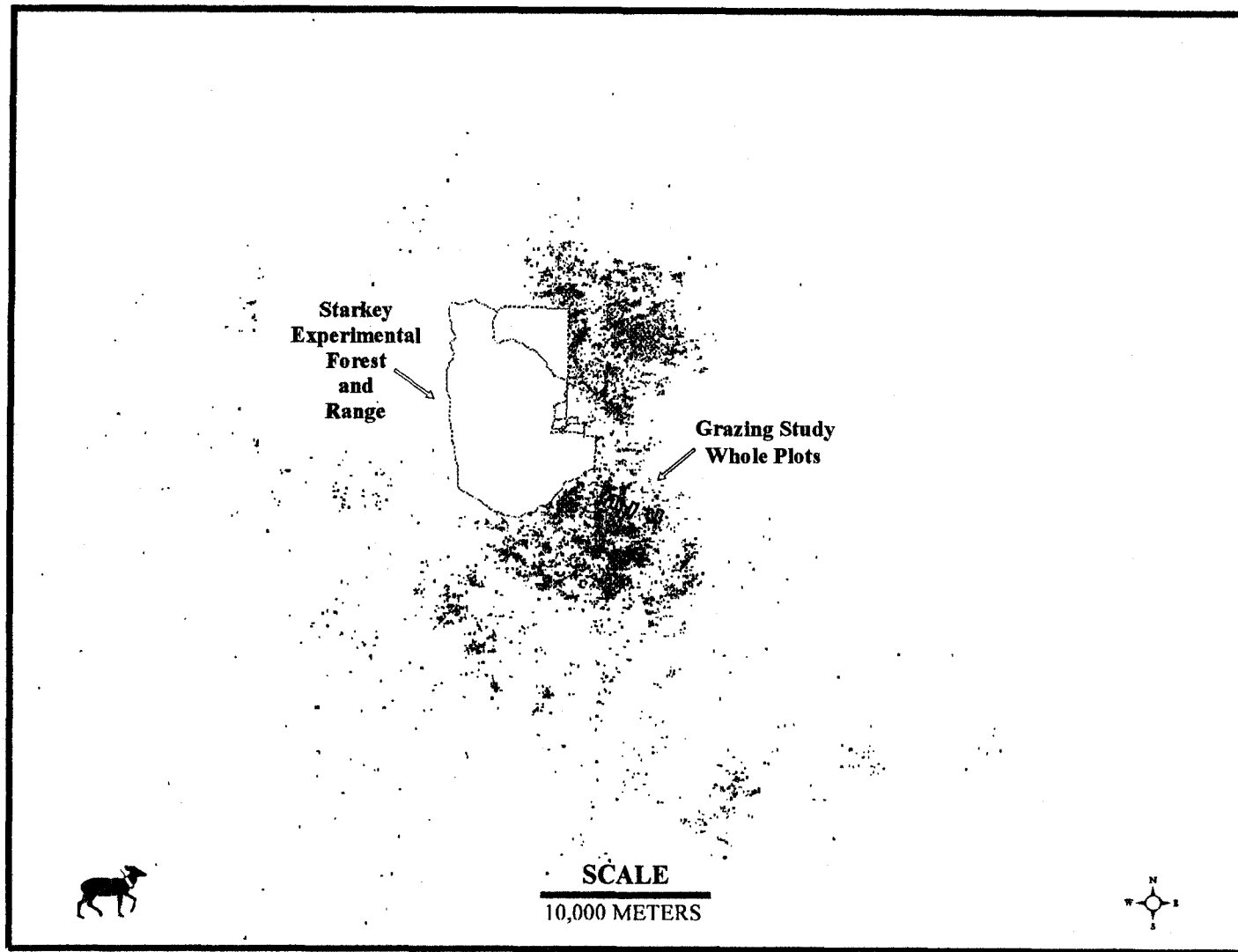
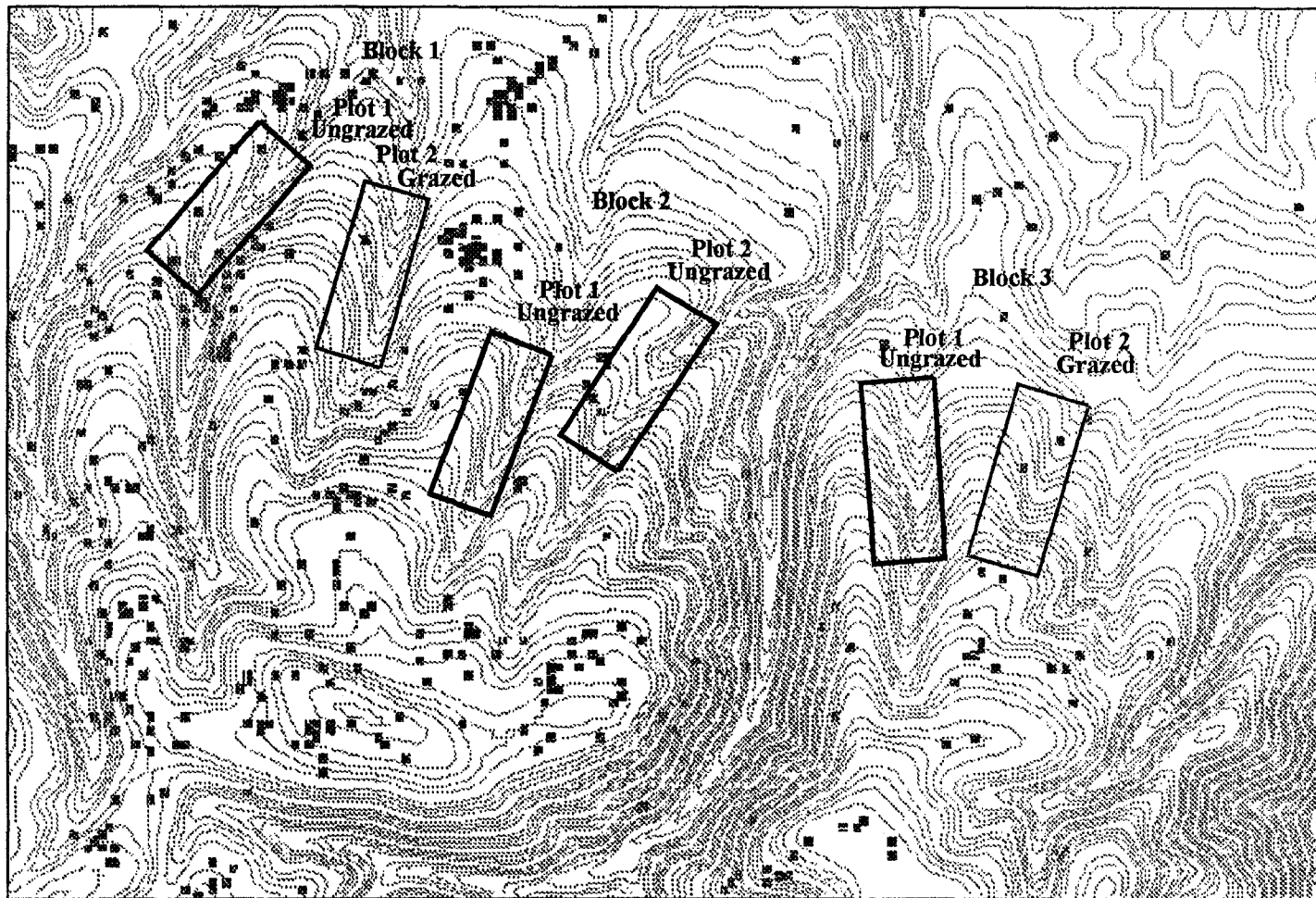


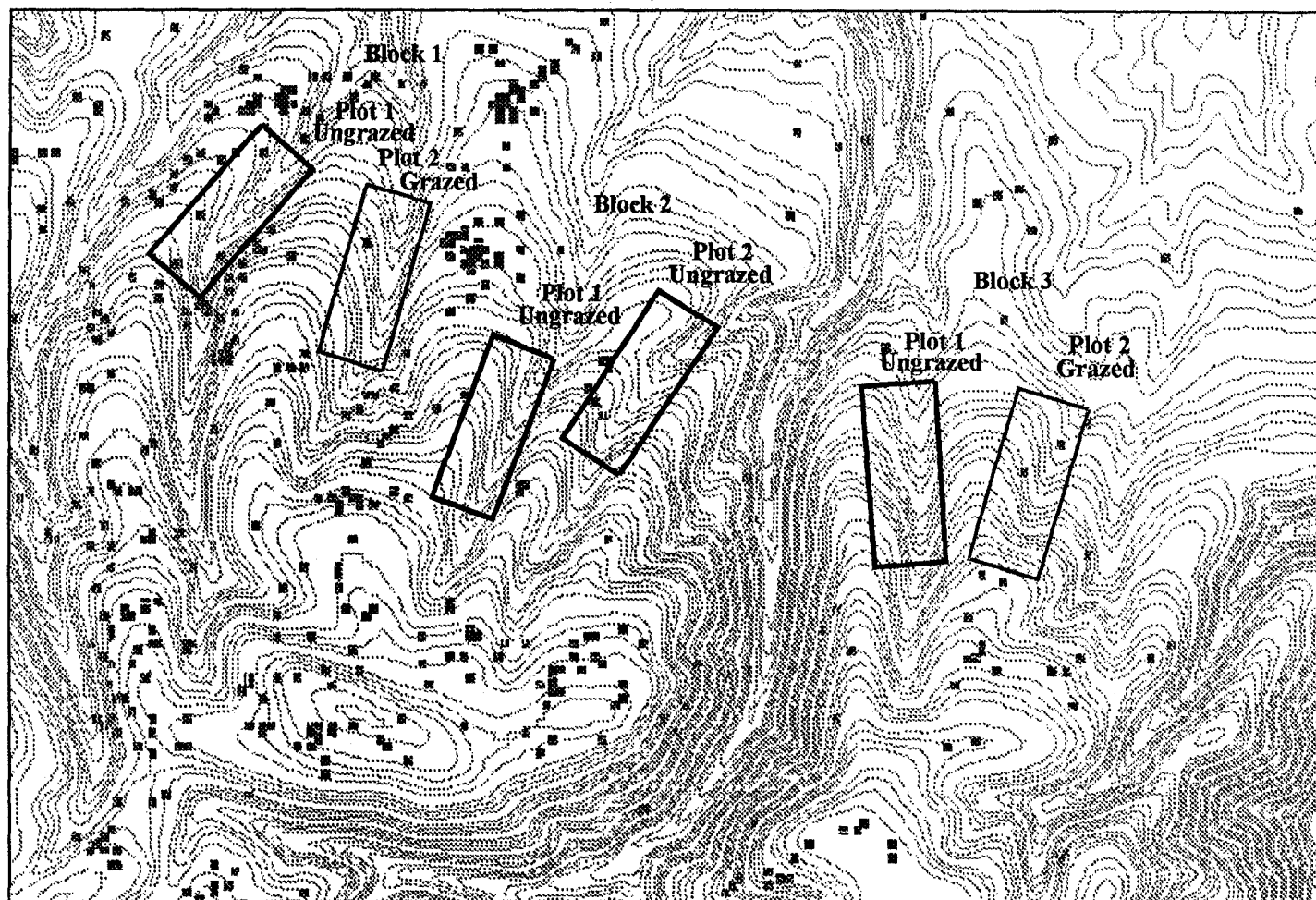
Figure 6.1 Telemetry elk locations collected during winters 1993-94 and 1994-95



SCALE
 1000 METERS
 (Contour Interval --10 meters)



Figure 6.3 Telemetry elk locations in and nearby the whole plots during winter 1994-95.



SCALE
 1000 METERS
 (Contour Interval -10 meters)



Figure 6.3 Telemetry elk locations in and nearby the whole plots during winter 1994-95.

Table 6.6 Canopy closure in the ecotone and stringer vegetation types.

Block	Plot	Vegetation Type	Canopy Closure (%)
1	1	Ecotone	13.2 (21.9958) ¹
		Stringer	43.6 (27.1150)
	2	Ecotone	13.6 (24.1235)
		Stringer	27.0 (30.9117)
3	1	Ecotone	12.4 (26.7608)
		Stringer	32.2 (30.5882)
	2	Ecotone	11.6 (25.5995)
		Stringer	26.5 (26.5323)

¹Standard deviations are enclosed within parentheses below the means.

Table 6.7 Maximum and minimum ambient temperatures for each vegetation type within the whole plots.

Subplot	Subplot End	Treatment	Max. Temp. --(°C)--	Min. Temp. --(°C)--
Grassland	North	Ungrazed	10.4	-8.8
		Grazed	10.1	-9.0
	South	Ungrazed	10.2	-8.8
		Grazed	11.2	-8.2
Ecotone	North	Ungrazed	10.0	-9.4
		Grazed	10.1	-9.5
	South	Ungrazed	10.2	-8.6
		Grazed	9.6	-8.9
Stringer	North	Ungrazed	9.4	-10.0
		Grazed	10.6	-9.9
	South	Ungrazed	8.6	-9.5
		Grazed	8.4	-8.8

¹Temperature data from max/min thermometers in each vegetation type at the north end of the whole plot are designated "North" and temperature data from the south end of the whole plot are designated "South".

Table 6.8 Mean wind speed for each of the vegetation types in Block 1 and Block 2 during winter 1994-95.

Subplot	Wind Speed Block 1 Whole Plot 2 ¹	Wind Speed Block 2 Whole Plot 2
	---(km/hr)---	---(km/hr)---
Grassland	3.5	2.9
Ecotone	2.1	1.6
Stringer	0.13	0.03

¹Wind speed data were collected from only one whole plot per block.

Mean wind speed did not differ ($P=0.1748$) between whole plots in Block 1 and 2 but highly significant differences ($P<0.0001$) were detected between vegetation types within whole plots (Table 6.8). Mean wind speed in the stringer vegetation types was lower ($P<0.05$) than in ridge or ecotone vegetation types. Mean wind speed in the ridge and ecotone vegetation types was similar ($P>0.05$). Mean snow depth in areas of no forest canopy (i.e. ridgetops and canopy openings) was similar ($P=0.4162$) between whole plots but differed significantly between vegetation types within whole plots ($P=0.0132$) (Table 6.9). Mean snow depth in the canopy openings of the stringer vegetation type was greater than in the ecotone openings or on the ridge vegetation type ($P<0.05$). No differences in mean snow depth were detected between the ridge and ecotone vegetation types ($P>0.05$). Mean snow depth in the open areas at northern and southern ends of the whole plots did not differ ($P=0.5641$). Under the forest canopy, mean snow depth was similar between whole plots ($P=0.3363$) and between the ecotone and stringer vegetation types ($P=0.3752$). No differences in mean snow depth under the forest canopy ($P=0.5239$) were detected between the northern and southern ends of the whole plots.

During the winter 1994-95, the mean percent sinking depth in snow for an adult cow elk was not significantly different between whole plots ($P=0.3393$), vegetation types ($P=0.6423$), or ends of the whole plots ($P=0.7763$) (Table 6.10). Differences in mean percent sinking depth were detected between open areas and under the forest canopy ($P=0.0042$). Mean percent sinking depth was greater in the open areas than under the forest canopy ($P<0.05$).

Although some real or possible differences in climatic factors existed between vegetation types within whole plots, none of the climatic factors analyzed appeared to be confounded with the forage utilization or plot occupancy response of wintering elk to the forage conditioning treatments at the whole plot level.

Table 6.9 Mean snow depth within each vegetation type of the whole plots.

Subplot	Subplot End ¹	Treatment	Snow Depth Open	Snow Depth Under
			--(cm)--	--(cm)--
Grassland	North	Ungrazed	4.4	na
		Grazed	6.1	na
	South	Ungrazed	6.6	na
		Grazed	6.1	na
Ecotone	North	Ungrazed	5.8	1.3
		Grazed	6.1	1.0
	South	Ungrazed	8.4	1.5
		Grazed	7.6	1.5
Stringer	North	Ungrazed	11.4	2.3
		Grazed	8.4	1.3
	South	Ungrazed	8.1	2.5
		Grazed	7.9	1.5

¹Snow depth data collected near the max/min thermometer at the north end of the whole plots are designated "North" and snow depth data collected in the south end of the whole plots are designate "South".

Table 6.10 Sinking depth and percent sinking depth relative to the depth of the snow pack in each of the vegetation types within the whole plots.

Subplot	Subplot End ¹	Treatment	Sinking Depth Open ²	Sinking Depth Cover	Percent Depth Open ³	Percent Depth Cover
			--(cm)--	--(cm)--	--(%)--	--(%)--
Grassland	North	Ungrazed	3.7	na	35.8	na
		Grazed	4.6	na	39.0	na
	South	Ungrazed	4.8	na	37.3	na
		Grazed	4.1	na	34.1	na
Ecotone	North	Ungrazed	4.1	1.3	36.7	25.0
		Grazed	4.3	1.5	41.5	18.8
	South	Ungrazed	4.8	1.3	43.6	25.0
		Grazed	5.6	2.3	36.9	24.8

Table 6.10. Continued

Stringer	North	Ungrazed	7.6	1.5	54.0	31.3
		Grazed	5.3	1.5	36.6	18.8
	South	Ungrazed	5.3	2.0	49.3	31.0
		Grazed	5.1	2.3	38.7	31.3

¹Sinking depth data collected near the max/min thermometers at the north end of the whole plots are designated "North" and sinking depth data collected in the south end of the whole plots are designated "South".

²Sinking depth data collected in the open areas are designated "Open" and sinking depth data collected under the ecotone and stringer forest canopy are designated "Cover".

³Percent sinking depth represents the sinking depth as a percentage of the depth of the snow pack.

6.6 Discussion

Neither the late spring sheep grazing treatment or the grazing exclusion treatment significantly influenced forage utilization or plot occupancy by elk wintering on the study area. Although some nonsignificant trends in forage utilization by elk appeared to exist, these trends may have been due to sampling error rather than actual differences in forage utilization between treatments.

Even if elk were attracted to the study plots in response to treatment effects on forage quality (see chapter 5), it is possible not enough elk wintered on the study area during 1993-94 and 1994-95 to produce a statistically significant amount of winter utilization of bluebunch wheatgrass, Idaho fescue, or elk sedge given precision of the field techniques used to estimate forage utilization in this study. During early spring (i.e., late March and early April), aerial census flights, Oregon Dept. of Fish and Wildlife personnel sighted 383 and 577 elk in and nearby the study area (i.e., within the Marley Creek drainage) in 1993 and 1994, respectively (Pers. Comm., Leonard Erickson, big game biologist, Oregon Dept. Fish and Wildlife, La Grande, OR. May 6, 1996).

Comparison of elk distribution on the study area during winters 1993-94 and 1994-95, as determined by telemetry locations, reveals some distinct habitat use patterns which were apparently similar between years (Figures 6.2 and 6.3). During winter 1993-94, three radio-collared elk occupied the plots in Block 1 and Block 3. Two radio-collared elk occupied Block 1 and Block 3 during winter 1994-95 and both of these elk were different from the radio-collared elk that occupied the plots in 1993-94. Interestingly, these different radio-collared elk used the same ridges and travel corridors, except the elk of winter 1994-95 made more use of the eastern half of the study area. Similar to the forage utilization results, no significant differences in plot occupancy by radio-collared elk were detected between treatments. Nonsignificant trends in plot occupancy appeared to exist, but these trends were contradictory between years. The apparent differences in plot occupancy may have been a response to established habitat use patterns by elk (i.e., use of connecting ridge systems for travel corridors) rather actual treatment effects on elk distribution. The ridge system on which Plot 1 of Block 1 was located appeared to be a travel corridor for elk moving north and south across the study area and the western side of the Starkey Basin. The clusters of telemetry locations collected near the northeastern corner and western side of Plot 1 of Block 1 were found to be bedding sites repeatedly used by elk wintering on the study area. Habitat features nearby Plot 1 of Block 1 may have accounted for the constancy elk occupancy of this plot between winters 1993-94 and 1994-95. None of the study plots seemed to be occupied by radio-collared elk for more than one to two days, suggesting the elk were traveling through the plots rather than being attracted to them in response to treatment effects.

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7. SUMMARY AND CONCLUSIONS

7.1 Clipping Experiment

Results from the clipping experiment (chapters 3 and 4) followed the predictions of Stoddart (1946). Those treatments which removed more herbage were more detrimental to plant vigor than less intensive treatments. Treatments applied later in the spring appeared to be more adverse than treatments applied earlier. The mid boot/whole plant, mid boot/half plant, and inflorescence emergence clipping treatments all enhanced the percent crude protein and percent *in vitro* dry matter digestibility in early winter samples of bluebunch wheatgrass compared to the unclipped control. The largest reductions in dry matter yield were observed in the mid boot/whole plant and inflorescence emergence treatments. The mid boot/half plant and control treatments were less detrimental to plant vigor, as measured by percent changes in basal area of individual plant, than were the mid boot/whole plant and inflorescence emergence treatments. Those treatments producing the highest improvements in forage quality (i.e., the mid boot/whole plant and inflorescence emergence treatments) generally had more detrimental effects on plant vigor than the other treatments.

Although significant differences were detected between the clipping treatments and the unclipped control treatment, none of the clipping treatments produced substantially large increases in the winter forage quality of bluebunch wheatgrass. The mid boot/half plant treatment exhibits some promise as a forage conditioning treatment that apparently has neutral or positive effects on plant vigor and enhances the nutritional value of bluebunch wheatgrass during winter compared to unconditioned forage.

7.2 Grazing Experiment

7.2.1 Forage Quality Response

The grazing experiment evaluated the effects of late spring defoliation by grazing sheep on the winter forage quality of Idaho fescue, elk sedge and bluebunch wheatgrass (chapter 5). Results on the forage quality response from the grazing treatments were less explicit than those obtained from the clipping treatments. Defoliation of forage graminoid species appeared to be much less precise under livestock grazing treatments compared to hand-clipping treatments. However, field observations suggested that the mid boot/half plant clipping treatment in the clipping experiment produced a visually similar defoliation pattern to that produced by grazing sheep.

Use of sheep as the forage conditioning agent may have resulted in less uniform utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge than if cattle had been used. Sheep are generally classed as

intermediate feeders since they consume a mixed diet of graminoids, forbs, and browse. Although sheep tend to consume proportionately more grasses than a classical intermediate feeder, their spring diets are dominated by forbs if palatable forbs are available. Where the availability of forbs is limited, sheep will selectively graze small, young grass plants and avoid older plants bearing standing litter accumulations. Selection for small, young grass plants likely continues until the supply of these plants becomes limiting and the energetic cost of seeking out small, succulent plants exceeds energy intake. Consequently, in grasslands and ponderosa pine savannas dominated by bunchgrasses, sheep apparently forage too selectively to provide an even and effective level of defoliation across large land areas within the narrow phenological window in which forage conditioning can successfully be applied to enhance winter forage quality.

As discussed in chapter 5, cattle also selectively graze phenologically younger grass plants over older plants bearing standing litter or reproductive culms. However, because cattle are grazers and graminoids dominate their spring diets, it is likely cattle would provide more even and intensive spring utilization of bunchgrasses than would sheep despite the influences of interplant selective grazing behavior.

7.2.2 Elk Response

The elk response to the grazing and grazing exclusion treatments was evaluated by estimating winter elk utilization of bluebunch wheatgrass, Idaho fescue, and elk sedge within the treatment plots and by comparing winter elk occupancy of the treatment plots via radio-telemetry. Both the forage utilization and plot occupancy results generally indicated no difference in elk response existed between the late spring sheep grazing treatment and the sheep grazing exclusion treatment.

The late spring utilization levels of bluebunch wheatgrass and Idaho fescue under the rotational cattle grazing at Bridge Creek Wildlife Management Area (BCWMA) near Ukiah, Oregon and the late spring utilization obtained under the grazing treatment of 1994 in the present study appear to be similar at roughly 50 to 60% for each species (Pers. Comm., David Harcombe, Area Manager, Bridge Creek Wildlife Management Area, Oregon Dept. of Fish and Wildlife, Pendleton OR, May 8, 1996). Although no differences were detected in the elk response between the late spring grazing treatment and the grazing exclusion treatment in the present study, a substantial increase in wintering elk numbers has been observed under the forage management system at BCWMA since in 1964 (Anderson and Scherzinger 1975). However, the increase in wintering elk at BCWMA is probably related to many factors and not solely a response to winter forage conditioning. From 1970 to the present, the BCWMA has been closed to motor vehicles between December and May. A sharp increase in the number of elk wintering on the BCWMA occurred during the early 1970s following the vehicle closure. The BCWMA appears to have served as a sanctuary from motor vehicle disturbance for wintering elk. It is possible the elk response to the forage conditioning at BCWMA may be subtle compared to the combined effect of all interacting factors operating at BCWMA. Bearing this in mind, it is also possible the elk response

to the grazing treatment in the present study was too subtle to be detected by the field techniques used to measure this response (i.e., ocular-estimate-by-plot utilization sampling and radio-telemetry) or perhaps the grazing treatments were not applied to large enough areas to elicit a detectable response by foraging elk.

7.3 Forage Conditioning: Forage Quality vs. Foraging Efficiency

Elk like other large ungulates are optimal foragers seeking to maximize energy intake efficiency by diet selection. Stuth (1991) describes two basic types of choices that influence the diet selection of grazing animals; spatial choices (i.e., the act of choosing feeding stations) and species choices (i.e., the act of choosing among plant species within a feeding station). Two additional levels might be added to this hierarchy of diet selection; plant choices (i.e., the act of choosing among individual plants of a species) and plant appendage choices (i.e., the act of choosing among plant appendages or portions of the plant).

Environmental factors such as topography and climate, behavioral factors such as social interaction and predator avoidance, and past experience with a particular landscape all probably strongly influence an elk's choice of a feeding station within that landscape. Visual, olfactory, or other sensory cues may also attract an elk to or deter an elk from a potential feeding station. Large areas of green regrowth produced following fire or livestock grazing may visually attract elk to establish feeding stations within those areas. The presence of plants with heavy litter accumulations may deter elk from an area. In the grazing experiment of the present study, we used radio-telemetry to assess the treatment response by wintering elk at the spatial choice level in the diet selection hierarchy. As mentioned above, it is possible we did not apply the grazing treatment to large enough areas to elicit an elk response detectable with radio-telemetry.

After an elk has arrived at a feeding station, choice between species may rely strongly on past experience. However, since differences in palatability and nutrient content between two species may vary depending on season and moisture conditions, sensory cues may also play an important part in species choice within a feeding station.

The influence of sensory cues on diet selection are probably most important in selection of individual plants and plant appendages. In the grazing experiment, we used forage utilization to evaluate the treatment response by wintering elk at the individual plant level of diet selection. Selecting plants and plant appendages with the highest nutrient content relative to their availability within a feeding station may allow a foraging elk to maximize energy intake efficiency. However, energy intake efficiency can only be maximized by selective foraging when more energy can be gained by selectively consuming a specific type of individual within a plant species (i.e., an individual with the highest nutrient density and nutrient availability to elk) or by consuming a specific plant appendage from a selected plant than is lost due to the costs of selective foraging.

Forage conditioning may influence the nutritional status of wintering elk by not only increasing the average winter forage quality within a plant species (chapter 3) but may also increase the availability of

preferred individual plant types within a species (i.e., individual plant types preferred by elk because of their higher nutrient density compared to other individual plant types). For example, assume wintering elk prefer green leaves over cured appendages or standing litter within individual Idaho fescue plants. If the availability of Idaho fescue plants with high green leaf content and the availability of Idaho fescue plants with heavy accumulations of standing litter were similar at a given feeding station and if the energetic return for selective foraging exceeded the costs, elk would be expected to consume proportionately more green, leafy Idaho fescue plants than Idaho fescue plants bearing standing litter. On a landscape where forage conditioning has not been applied, there would probably be a relatively small number of individual Idaho fescue plants that would be preferred by wintering elk because of their high green leaf availability and correspondingly high energy yield per plant. These preferred plants would likely occur as individuals or small clusters of individuals (i.e., patches) widely scattered across the landscape. If wintering elk established feeding stations based on the location of these preferred plants, the added energy costs from the resultant increase in search time and travel distance between feeding stations probably would exceed the gain in energy intake per plant. Forage conditioning may delay plant phenology and remove accumulations of standing litter from Idaho fescue creating a higher density of preferred plants (i.e., creating more patches of preferred plants) within a landscape. If enough of these preferred plants are made available on the landscape, wintering elk may be able to improve their nutritional status by selectively grazing these preferred plants.

The success of using forage conditioning as a tool to manage winter elk distribution and improve the nutritional status of wintering elk likely depends on the size of the area being treated, the relative improvement in forage quality and forage accessibility produced by the conditioning treatment compared to unconditioned areas and year to year variations in the body condition of the elk as they enter the winter.

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