THE INFLUENCE OF STRATEGIC PROTEIN SUPPLEMENTATION ON LATE SUMMER CATTLE GRAZING BEHAVIOR, DIET COMPOSITION, PERFORMANCE AND UTILIZATION OF RIPARIAN VEGETATION IN MOUNTAIN RIPARIAN AREAS

A Thesis

Presented in partial Fulfillment of the Requirements for the

Degree of Master of Science

with a

Major in Rangeland Ecology and Management

In the

College of Graduate Studies

University of Idaho

By

Angela D. Jemes Freeman

April 30, 2007

Major Professor: Dr. Karen Launchbaugh

AUTHORIZATION TO SUBMIT THESIS

This thesis of Angela D. James Freeman, submitted for the degree of Master of Science with a major Rangeland Ecology and Management and titled “The influence of strategic protein supplementation on late summer cattle grazing behavior, diet composition and quality, performance and utilization of riparian vegetation in mountain riparian areas”, has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor ______________________________ Date ________________
Dr. Karen Launchbaugh

Committee Members ______________________________ Date ________________
Dr. Timothy DelCurto

______________________________ Date ________________
Dr. Stephen Bunting

Department Administrator ______________________________ Date ________________
Dr. Karen Launchbaugh

Discipline’s College Dean ______________________________ Date ________________
Dr. Steven Daley Laursen

Final Approval and Acceptance by the College of Graduate Studies

______________________________ Date ________________
Dr. Margrit von Braun

ABSTRACT

This study was designed to quantify the effect of strategic protein supplementation on the distribution and vegetation utilization patterns of cattle grazing in mountain riparian areas in late summer. Late summer is the season when, depending on environmental and forage conditions, cow nutritional requirements may exceed forage quality and forage quality varies with landscape features. From 15 July to 27 August 2004 and 2005, 2 treatments were randomly assigned to 1 pasture in each of 3 blocks. Sixty cow/calf pairs were stratified by age and randomly allotted to the pastures/experimental units. Treatments included: 1) chemically hardened molasses protein supplement (30% crude protein (CP) with TiO_2 marker) and 2) no supplement (control). Supplement was strategically placed in upland locations averaging 267 m from the stream. Stocking rates to achieve moderate utilization ranged from 0.6-1.2 AUM/ha based on previously established estimates of production for each pasture. Cattle consumed supplement at the rate of 1.59 kg pair^{-1} day^{-1}. Distribution data were collected for an intensive four-day sampling period from day 21 to day 24 of the study. Supplemented cattle showed a preference for the uplands as compared to cattle without supplement ($P < 0.0001$). Utilization of riparian grass decreased 7% ($P = 0.003$) utilization of greenline vegetation tended to decrease 12% ($P = 0.063$) and utilization of upland vegetation increased 8% ($P = 0.025$) in supplemented pastures. Likewise, riparian grass stubble heights were 5.5 cm higher ($P = 0.006$) and greenline stubble heights were 5.46 cm higher ($P = 0.006$) in pastures with strategically placed supplement. Our results suggest that strategic protein supplementation can be an effective tool to decrease grazing livestock's use of the riparian area during late summer and can, as a result, conserve riparian vegetation.

ACKNOWLEDGEMENTS

Completing this project would have been impossible without the help of many people. I'd like to thank my family for their support and love. My wonderful kids Sammy and Levi were helpful in the field, patient at home and always cheering me on. Though neither of my parents went to college they valued education and supported me without fail. I have to thank my brother Brian as well for reminding me that doing something you love may take time away from your family, but it also fills your life with an energy and purpose. I'd also like to thank the staff at EOARC. They were helpful, supportive and patient and we had some good laughs working together. I have to especially thank Tim who quietly stood in as my major professor by default when I needed him. His humor, calm outlook and good advice on everything from writing to fence building kept this study on track when road blocks came up. I want to thank Karen for her continual inspiration as a brilliant, passionate advocate for range and for the time and encouragement she has given me as a mentor. Now for the saddest and most important thank you. During my project my friend, mentor and major professor Jeff Braatne passed away after a courageous battle with cancer. I can't thank Jeff enough for believing in me and my abilities at a time when it was hard for me to believe in myself. So many times it was his belief in me and a gentle push that led me to try something and then discover that I was capable of it. He was smart, funny and kind, a brilliant scientist and writer and an excellent coach. Thank you Jeff for giving me the tools and the confidence to complete this project. You are greatly, greatly missed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

I. MANAGEMENT STRATEGIES FOR OPTIMAL GRAZING DISTRIBUTION IN MOUNTAIN RIPARIAN ECOSYSTEMS

IMPORTANCE OF RIPARIAN ZONES

Riparian areas are the assemblages of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are water-induced or related (Kauffman and Kreuger, 1984). Although the geographic extent of riparian areas is limited, they display high levels of productivity and biodiversity. Naiman (1993) describes riparian corridors as “the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the earth”. Riparian vegetation provides many ecological functions including: plant diversity, diverse fish and wildlife habitat, sediment filtration, soil and streambank stabilization, regulation of water temperature, nutrient cycling, and aquatic and riparian food web support (National Research Council, 2002; Powell et al., 2000). The higher quality and quantity of the forage found in riparian areas also makes them economically important to livestock production in the Pacific Northwest (DelCurto et al., 2005). The ecological and economic importance of riparian areas emphasizes the need for optimal management strategies.

Riparian Grazing

The impacts of cattle grazing on riparian areas are complex and varied, but concerns usually arise from uneven grazing distribution (Bailey, 2004; DelCurto et al., 2005; Fleisvchner, 1994). Cattle tend to use riparian areas at disproportionately higher rates than adjacent uplands (Parsons et al., 2003; Smith et al., 1992a). Many studies report that improper grazing of riparian vegetation have negative impacts on both riparian and aquatic ecosystems (Belsky et al., 1999; Fleischner, 1994; Kauffman et al., 1997). These impacts can include: increased soil erosion, increased stream bank instability, reduction in water quality, net loss of water storage, and decreases in plant and animal habitat quality resulting in decreases in biodiversity and productivity (DelCurto et al., 2005; Powell et al., 2000).

For example, woody riparian vegetation is especially vulnerable to improper grazing (Gregory et al., 1991; National Research Council, 2002). Woody plants are vital to the ecological integrity of riparian and aquatic habitats providing streambank stability, nutrient cycling, food web support, wildlife habitat, and contributing large woody debris (Braatne et al., 1996). Over-utilization can prevent sustainable growth and reproduction of woody vegetation and may have wide spread and lasting effects on the riparian ecosystem. Peinetti et al., (2001) found that high levels of elk herbivory in Rocky Mountain National Park reduced the competitive ability and survivorship of willows (*Salix* spp.). Kay and Chaddle (1991), using long term exclosures in Yellowstone National Park, saw that high levels of browsing by elk, reduced willow seed production by 100%.

Late summer tends to exacerbate uneven grazing distribution in riparian areas. This has been documented consistently in the Intermountain and Pacific Northwest regions. Studies in Montana found that in late summer cattle spent a disproportionate amount of their feeding time in the riparian zone (Pogacnik and Marlow, 1986). An extensive survey of U.S. Forest Service and Bureau of Land Management grazing lands found that willows were grazed most heavily in the mid to late summer grazing (Elmore and Kovalchik, 1991). Studies in Wyoming, found that floodplain habitats were preferentially selected during late summer grazing in both small and large pastures and woody plants were more severely grazed than other species (Smith et al., 1992a, 1992b).

Uneven late summer cattle grazing distribution has also been documented specifically at the study site on Milk Creek in research conducted by the Eastern Oregon Agricultural Research Center (EOARC) in northeastern Oregon. In late summer, grasses and forbs decrease dramatically in quantity and quality, while riparian shrubs maintain consistently high levels of protein and moisture. The use of riparian shrubs increases as the quality of the grass and forbs declines throughout the season (Darambazar et al., 2003). Late summer shrub use by cattle was noted in data collected using fistulated heifers (Vavra and Phillips, 1979). A grazing exclosure study documented late season shrub use by cattle (Kauffman et al., 1983a), and 12 years later an overall reduction in the height and density of woody riparian species outside the grazing exclosures was noted (Green and Kauffman, 1995). A comparison of habitat selection throughout the growing season documented a late summer shift in cattle distribution and diets resulting in higher use of riparian habitats and vegetation (Parsons et al., 2003).

Management of Riparian Grazing Distribution

Riparian grazing management strategies that decrease use of the riparian area and promote the subsequent riparian habitat benefits are imperative to ensure the sustainability of livestock grazing on private and public land (DelCurto et al., 2005). Public lands are managed for multiple objectives and must comply with several policies and laws such as the 1973 Endangered Species Act and the 1972 Clean Water Act. Restricting livestock access to the riparian ecosystem is commonly suggested as a primary method of controlling cattle distribution and utilization (Kauffman et al., 1997; National Research Council, 2002). However, reviews of the riparian grazing management literature are critical of existing studies and call for further research (National Research Council, 2002; Powell et al., 2000).

Livestock grazing management strategies to alter cattle distribution and vegetation utilization have been studied throughout the Intermountain West and Pacific Northwest regions including research in eastern Oregon at the study site on Milk Creek. These include: developing off stream water, altering stocking rate and density, changing season of use, and selecting grazing animals by “type” (age, breed, reproductive status or individual behavior), providing shade, burning, fertilizing, fencing for exclusion or concentration of cattle, herding, and providing strategic supplementation (Bailey, 2004; DelCurto et al., 2005).

Water developments can influence and abruptly change the spatial foraging patterns of cattle (Ganskopp, 2001; Gillen et al., 1984). Off stream water developments were found to decrease grazing pressure in the riparian area (Porath et al., 2001). Off stream water developments may decrease riparian use, but effectiveness tends to decrease as forage quantity and quality declines.

Stocking rates and stocking densities are often altered in an effort to increase uniformity of forage use. A reduction in stocking rate may not produce the desired vegetation utilization changes. Huber et al., (1995) found that cattle stocked at low rates spent more time grazing riparian vegetation than cattle stocked at moderate rates. Increasing stocking densities, usually obtained by using smaller pastures and rotating cattle through them more frequently, has been found to have variable effects on the uniformity of grazing depending on the pasture size and distance to water (Bailey, 2004).

Selecting different seasons of use can alter cattle grazing distribution. For example, in mountain pastures upland forage quality and utilization tends to be higher in spring and early summer (Parsons et al., 2003). Grazing when forage is dormant another strategy to encourage more uniform distribution. However, these strategies do not address late summer when forage quality, depending on environmental conditions, may be below cattle nutritional requirements.

The selection of cattle based on “type” (individual behavior, breed, age, reproductive status) can result in changes in grazing behavior. Different breeds of cattle have been found to distribute differently on rough terrain (Bailey et al., 2001a). Individual selection, or “culling” was also found to be effective in changing distribution and decreasing riparian use (Howery et al., 1996). A “cross-fostering” experiment by Howery et al., (1998) also demonstrated that early experiences and learned behavior are important in determining cattle distribution later in life. Age and reproductive status also effect distribution patterns. Morrison et al., (2002) found that older cows spent less time in the riparian area and non-lactating cows used steeper slopes and higher elevations than lactating cows (Bailey et al., 2001a). These changes in distribution may be overridden by other factors such as social interactions or attributes of the pasture.

Techniques to change pasture attributes such as providing shade, burning or fertilizing have also been studied. These techniques are expensive and shade has been found to improve animal performance, but not the uniformity of distribution (Bailey, 2004; DelCurto et al., 2005).

Strategically placed fences can group like plant communities together increasing the uniformity of grazing distribution (Bailey, 2004). Fences can also specifically reduce or eliminate grazing of a sensitive habitat type. However, little is known about the long-term ecological implications of exclusionary fencing (Bryant, 1982; Green and Kauffman, 1995; Kauffman et al., 2002; Sarr, 2002).

Herding is a traditional method of altering cattle distribution, but results have varied. Some have found herding to be expensive and ineffective (Rhodes and Marlow, 1997) while others suggest that regular herding is an effective tool to protect riparian areas (Butler, 2000; Skovlin, 1957).

Effects of Protein Supplementation

The list of techniques with potential for altering grazing distribution of cattle is long and varied, but most have been found to be only partially effective as well as difficult and/or expensive to implement. In contrast, protein supplementation (beginning when upland forages lose nutritional quality and ending when the shrubs shed their leaves) may be an effective tool to improve grazing distribution. Ares (1953) documented a 50% decrease in areas of excessive cattle use (as defined in his protocol) when a cottonseed meal-salt supplement was strategically placed on rangeland in the southwestern US. A similar study provided strategically placed block salt with and without meal-salt, but found there was just a trend toward more uniform distribution (Martin and Ward, 1973). Strategic placement of protein supplement resulted in an increase of residual dry matter in the riparian areas of hardwood rangeland in California from 13% to 72% (McDougal et al., 1989). Bailey and Welling (2001) found that cattle grazing northern Montana rangelands in fall and early winter spent more time and grazed more in areas where supplement was strategically placed including increased use of areas that were steeper and/or at greater distances from water. Bailey et al., (2001b) also measured increasing forage use up to 600 m from strategically placed supplement on northern Montana rangelands in early fall, late fall and early winter. Another study measured the use of low moisture molasses block (LMB) and conventional dry mineral mix (CDM) by cattle grazing Montana rangeland. Cattle visited the LMB more consistently suggesting that

LMB has higher potential to modify grazing distribution than CDM especially when placed off stream and in rough terrain (Bailey and Welling, 2007).

CONCLUSION

Today's landowners and managers are under pressure to manage land for multiple values with limited economic resources. Riparian area protection is often the focal point for this pressure. These areas are valuable because of the numerous ecosystem services they provide including: plant diversity, diverse fish and wildlife habitat, sediment filtration, soil and streambank stabilization, regulation of water temperature, nutrient cycling, and aquatic and riparian food web support. They are also important because of the resources they provide to conservationist, cattle producers and other interest groups.

Strategic protein supplementation is one such management strategy. While this appears to be a reasonable management option, there is limited literature available that quantifies the effect of strategically placed protein supplement on cattle distribution and forage utilization in riparian pastures in late summer. As such, this technique cannot be confidently incorporated into management plans without documentation of its effectiveness. This creates a need to evaluate the effect of strategic protein supplementation on cattle distribution and vegetation utilization relative to riparian pastures.

This thesis reports results of a research project that assesses the effect of strategic protein supplementation on cattle distribution and vegetation utilization relative to riparian pastures. The goal of conducting this research is to provide information to land managers seeking to develop practical, sustainable solutions that balance the ecological and economic needs of livestock producers in the semi-arid West.

II. STRATEGIC PROTEIN SUPPLEMENTATION OF BEEF CATTLE GRAZING MOUNTAIN RIPARIAN PASTURES

ABSTRACT

This study was designed to quantify the effect of strategic protein supplementation on the distribution and vegetation utilization patterns of cattle grazing in mountain riparian areas in late summer. Late summer is the season when, depending on environmental and forage conditions, cow nutritional requirements may exceed forage quality and forage quality varies with landscape features. From 15 July to 27 August, 2004 and 2005, 2 treatments were randomly assigned to 1 pasture in each of 3 blocks. Sixty cow/calf pairs were stratified by age and randomly allotted to the pastures/experimental units. Treatments included: 1) chemically hardened molasses protein supplement (30% crude protein (CP) with TiO_2 marker) and 2) no supplement (control). Supplement was strategically placed in upland locations averaging 267m from the stream. Stocking rates to achieve moderate utilization ranged from 0.6-1.2 AUM/ha based on previously established estimates of production for each pasture. Cattle consumed supplement at the rate of 1.59 kg $pair^{-1}$ day^{-1}. Distribution data were collected for an intensive four-day sampling period from day 21 to day 24 of the study. Supplemented cattle showed a preference for the uplands as compared to cattle without supplement ($P <$ 0.0001). Utilization of riparian grass decreased 7% ($P = 0.003$), utilization of greenline vegetation tended to decrease 12 % ($P = 0.063$) and utilization of upland vegetation increased 8% ($P = 0.025$) in supplemented pastures. Likewise, riparian grass stubble heights were 5.5 cm higher ($P = 0.006$) and greenline stubble heights were 5.46 cm higher ($P = 0.006$) in pastures with strategically placed supplement. Our results suggest that strategic protein supplementation can be an effective tool to reduce livestock grazing impacts in the riparian area during late summer and, as a result, conserve riparian vegetation.

KEYWORDS: grazing, beef cattle, riparian, protein supplementation, distribution

INTRODUCTION

Riparian areas are the assemblages of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are water-induced or related (Kauffman and Kreuger, 1984). Although the geographic extent of riparian areas is limited, they display high levels of productivity and biodiversity (Naiman et al., 1993). Riparian vegetation provides many ecological functions including: diverse fish and wildlife habitat, sediment filtration, soil and streambank stabilization, regulation of water temperature, nutrient cycling and aquatic and riparian food web support (National Research Council, 2002; Powell et al., 2000). The higher quality and quantity of the forage found in riparian areas also makes them economically important to livestock production in the Pacific Northwest (DelCurto et al., 2005). The ecological and economic importance of riparian areas emphasizes the need for optimal management strategies to meet diverse objectives.

The impacts of cattle grazing on riparian areas are complex and varied, but concerns usually arise from uneven grazing distribution (Bailey, 2004; DelCurto et al., 2005; Fleischner, 1994). Cattle tend to disproportionately use riparian areas compared to adjacent uplands (Parsons et al., 2003; Smith et al., 1992a). Many studies and observations have reported that improper grazing of riparian vegetation has negative impacts on both riparian and aquatic ecosystems (Belsky et al., 1999; Fleischner, 1994; Kauffman et al., 1997). These impacts include: increased soil erosion, decreased bank stability, reduced water quality, net loss of water storage, and decreases in plant and animal habitat quality resulting in decreased in biodiversity and productivity (DelCurto et al., 2005; Powell et al., 2000).

Grazing distribution tends to become even more spatially uneven during late summer. This has been documented consistently in the Intermountain and Pacific Northwest regions with studies across ownerships and regions in the western states finding that in late summer cattle spent a disproportionate amount of their feeding time in the riparian zone (Elmore and Kovalchik, 1991; Pogacnik and Marlow, 1986; Smith et al., 1992a, 1992b). At the Eastern Oregon Agricultural Research Center (EOARC) in northeastern Oregon a series of studies suggest that as forage quality and quantity declines, cattle display a disproportionate preference for riparian vegetation (Darambazar et al., 2003; Morrison et al., 2002; Parsons et al., 2003; Porath et al., 2001; Vavra and Phillips, 1979).

Riparian grazing management strategies that discourage overuse of the riparian area in order to maintain or improve the condition of the riparian vegetation are imperative to ensure the sustainability of livestock grazing on private and public land (DelCurto et al., 2005). Public lands are managed for multiple objectives and must comply with numerous policies and laws such as the 1973 Endangered Species Act and 1972 Clean Water Act. Livestock grazing management strategies to change cattle distribution and alter vegetation utilization patterns have been studied throughout the Intermountain West and Pacific Northwest region. These include: water development, changes in stocking rate, altering season of use, selecting grazing animals by age, breed, reproductive status or individual characteristics, providing shade, burning, fertilizing, fencing for exclusion or concentration of cattle, herding, and strategic supplementation (Bailey, 2004; DelCurto et al., 2005).

The list of techniques with potential for altering the grazing distribution of cattle is long and varied, but most have been found to be only partially effective and difficult and/or expensive to implement. Protein supplementation (beginning when upland forages lose nutritional quality and ending when the shrubs shed their leaves) may improve grazing distribution with minimal effort and low cost. Ares (1953) documented a 50% decrease in areas of excessive cattle use (as defined in his protocol) when a cottonseed meal-salt supplement was strategically placed on rangeland in the southwestern U.S. Another study in the southwestern US provided strategically placed block salt with and without meal-salt, but found there was just a trend toward more uniform distribution (Martin and Ward, 1973). Strategic placement of protein supplement resulted in a 13 to 72% increase of residual dry matter in the riparian areas of hardwood rangeland in California (McDougal et al., 1989). Bailey and Welling (2001) found that cattle grazing northern Montana rangelands in fall and early winter spent more time and grazed more in areas where supplement was strategically placed including increased use of areas that were steeper and/or at greater distances from water. Bailey et al., (2001b) also measured increasing forage use within a 600 m radius from strategically placed supplement on northern Montana rangelands in early fall, late fall, and early winter. Another study measured the use of low moisture molasses block (LMB) and conventional dry mineral mix (CDM) by cattle grazing Montana rangeland. Cattle visited the LMB more consistently suggesting that LMB has higher potential to modify grazing distribution than CDM especially when placed off stream and in rough terrain (Bailey and Welling, 2007).

Riparian ecological and economic values, public pressure, and legal restrictions create a pressing need for continuing research on practical and economical strategies for riparian grazing management that emphasizes improved cattle distribution. Strategic protein supplementation is one such management strategy. While this appears to be a reasonable management option, there is limited published research available that quantifies the effect of strategically placed protein supplement on cattle distribution and forage utilization in riparian pastures in late summer. This research project seeks to provide a replicated, quantitative assessment of the effect of strategic protein supplementation on cattle distribution, and vegetation utilization in mountain riparian pastures in late summer.

METHODS

Study Site

This study was conducted on Oregon State University's Eastern Oregon Agricultural Research Center's "Hall Ranch" located in the foothills of the Wallowa Mountains in northeastern Oregon (lat 45°7'48"N, long 117°42'32"W). Elevation is approximately 1,015 m. Annual precipitation averages 35 cm with over 60% occurring as snow during the winter months. Total July and August rainfall averages 3.94 cm and average July and August evaporation totals 35.38 cm (Taylor et al., 1993). The climate includes cold, snowy winters and hot, dry summers that provide limited potential for vegetative re-growth July through September.

The study incorporated 109 ha of riparian meadow and adjacent uplands bordering Milk Creek, a narrow, low gradient, perennial, spring fed stream that is a tributary to Catherine Creek. Catherine Creek is a third order tributary of the Grande Ronde River. This basin provides both spawning and rearing habitats for three species of resident and anadromous fish species, the Snake River steelhead (*Oncorhynchus mykiss gairdneri*), Snake River spring/summer chinook (*Oncorhynchus tshawytscha*) and bull trout (*Salvelinus confluentus*) which are federally threatened as listed by the United States Fish and Wildlife Service (Trask, 2001).

The study site was stratified into three blocks based on vegetation type. Blocks (*n* = 3) were cross-fenced with electric fence to create six pastures (Figure 2-1). Four pastures were about 13 ha and 2 were 25 ha. Vegetation and species composition data previously collected on the study site were used to classify vegetation communities and estimate production. Pasture size was based on the average vegetation production per hectare in order to obtain a uniform utilization level at a set stocking rate between all pastures (Porath et al., 2001). Pastures five and six had a larger area to compensate for lower production due to a dense overstory canopy and a smaller riparian area. Within each pasture the vegetation was classified into three vegetation types: riparian grass, riparian sedge rush, and upland.

Riparian grass communities are those which inhabit the active floodplain and consist of > 50% grasses by weight. Grass species included Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis alba)*, meadow foxtail (*Alopecurus pratensis*), timothy (*Phleum pretense*), and brome (*Bromus* spp.). Sedges (*Carex* spp.) and rushes (*Juncus* spp.) and numerous forbs including tall buttercup (*Ranunculus acris*), red clover (*Trifolium pretense)*, northwest cinquefoil (*Potentilla gracilis*), stream bank butterweed (*Senecio pseudaureus*), fleabanes (*Erigeron* spp.), western yarrow (*Achillea millefolium*), and lupines (*Lupinus* spp.) were also present. The dominant woody species include Douglas' hawthorne (*Crataegus douglasii)*, thinleaf alder (*Alnus incana*), common snowberry (*Symphoricarpos albus*), Mackenzie willow (*Salix rigida*), wild rose (*Rosa woodsii*), and ponderosa pine (*Pinus ponderosa*) and black cottonwood (*Populus trichocarpa*).

Riparian sedge/rush communities are located in the active floodplain as well, but are distinctive due to the presence of > 50% sedge and/or rush species by weight. Other species present are the same as the riparian grass community.

Upland communities are those present outside the active floodplain and are typically dominated by grasses. These include timothy (*Phleum pretense*), orchard grass (*Dactylus glomerata*), needlegrass (*Stipa* spp.), bromes (*Bromus* spp.), Idaho fescue (*Festuca idahoensis),* Kentucky bluegrass (*Poa pratensis*), pinegrass (*Calamgrostis rubescens*), elk sedge (*Carex geyeri*), a variety of forbs, and patches of shrubs including common snowberry (*Symphoricarpos albus*), spirea (*Spirea splendens*), and ceanothus (*Ceanothus* spp.). Most of the uplands have an overstory of ponderosa pine (*Pinus ponderosa),* but some areas are open meadows.

Six riparian pastures were used over a two-year period in a 2x2 cross-over design with three blocks of the following two treatments: 1) chemically hardened molasses protein supplement (30% crude protein [CP] with TiO_2 marker;(Steele and Torrie, 1980); and 2) no supplement (control). Each treatment was randomly assigned to one pasture within each of the 3 blocks. In mid-July of each year, sixty cow/calf pairs (angus-cross, avg. wt = 533 kg, SE = 14 kg) were stratified by age and randomly assigned to the 6 pastures. Pastures were stocked with 10 pair to achieve moderate utilization from July 15 to August 27 (42 days). Stocking rates were 1.2 AUM/ha in the 13 ha pastures and 0.6 AUM/ha in the 25 ha pastures. Milk Creek, a perennial stream that flowed through all the pastures was the only water source for livestock grazing the pastures.

Protein supplement was provided in the form of a chemically hardened molasses block with 30% crude protein packaged in a 100 kg tub. The supplement consisted of molas-ses products and the predominant protein sources were 18% plant products (soybean meal, canola meal and urea) and 12% non-protein nitrogen (urea). The supplement was formulated for an expected consumption rate of 1 kg $pair^{-1}$ day^{-1}. Less than 1% of an indigestible white powder, titanium dioxide (TiO_2) was added as a marker to the supplement for use in fecal analysis (Meyers et al., 2004). Supplemental protein was provided *ad libitum* and was checked on a regular basis. To ensure familiarity with the supplement, cattle were given access to the supplement for a month during the winter feeding period. Loose mineral salt was provided *ad libitum* in supplement and control pastures each year at the supplement sites.

Supplement Consumption

Total supplement consumption per pasture was measured by weighing each tub of supplement delivered to each pasture, subtracting an average container weight and weighing out any remnants at the close of the study.

Cattle Distribution

Distribution of cattle in pastures was assessed by visual observations during a four-day period from day 21-24 of the study. Distribution data were collected hourly between 0600 and 1900. Large numbers were painted on the side of each cow to facilitate identification. The location of each adult animal was recorded by 3 observers on geographically corrected aerial photos overlaid with the fence polygons with a scale and accuracy of 1 m, 1 in each block. Over 1,600 locations were recorded each year of the study. These locations were then digitized using the Geographic Information Systems (GIS) program *Idrisi 32 for Windows*™ (Clark University, Worcester, Massachusetts). The pastures were divided into riparian and upland portions based on plant community composition. All the observations were then classified as riparian or upland. The percentage of riparian and upland observations at each hour within each treatment was then compared.

Vegetation Utilization and Stubble Height

Three equally spaced transects perpendicular to Milk Creek running the lengths of each pasture were established each year. Every 10 m along the transect, observers examined a 0.25 m^2 observation point and 1) assigned the utilization class using an ocular estimate technique, 2) estimated the average stubble height, and 3) classified the plot according to the vegetation type (riparian grass, riparian sedge/rush, upland) in which it occurred. Additional measurements were taken in the "greenline" portion of each transect. The "greenline," a linear belt of perennial vegetation along the water's edge, most often occurring at or slightly below the bankfull stage (Winward, 2000), was considered to be the area within 1 m of each side of the stream for the purposes of this study. Four 0.25 m^2 plots were placed in this area. The first plot was placed 1 m from the water's edge, the second was placed 1 m upstream, the third 1 m from the water's edge on the opposite bank, and the fourth 1 m downstream.

Ocular vegetation utilization estimates were made using modifications of the methods established by Pechanec and Pickford (Pechanec and Pickford, 1937). Utilization was estimated by a visual assessment of the amount of forage removed by weight. Observers assigned one of the following five classes to each observed plot: 1) 0%, 2) 1-25%, 3) 26-50%, 4) 51-75%, and 5) 76-100%.

Three observers were trained to recognize these classes before the study began. Each observer independently estimated use on ten 0.25 m^2 plots that had been previously clipped (and weighed) to represent different levels of use. After estimates were made the remaining standing vegetation was clipped to within 2 cm of the ground and weighed.

The estimated utilization was then regressed against the actual utilization values to develop a regression equation for each observer. The equations were later used to correct the ocular utilization estimates taken during the trial for the individual observer bias.

Placing a ruler in the center of the 0.25 m^2 plot and measuring the stubble height to the nearest cm estimated remaining herbaceous stubble height. Over the 2-year study more than 3,000 individual utilization estimates and stubble heights were collected.

Statistical Analysis

Data were analyzed using GLM procedures of SAS (SAS, 1996) as a two treatment, replicated, cross-over design. Pasture was the experimental unit and supplement was the treatment. Data collected on individual animals and plant communities within a pasture were compiled into an average measurement per pasture for that treatment. Time series data such as utilization at day 21 and day 42 were analyzed as a mixed repeated measures design. Means were separated using least square means procedure of SAS and were considered significantly different at the ($P < 0.05$) level.

RESULTS

Supplement Consumption

Cattle consumed supplement at the rate of 1.59 kg $pair^{-1}$ day^{-1} in 2004 and 2005. Protein supplement was readily consumed when provided in late summer in the uplands of riparian pastures. Consumption rates were more than double the predicted amount.

Distribution

Strategic supplementation altered distribution patterns and in turn, resource utilization patterns. Supplemented cattle showed greater use of the uplands as compared to cattle without supplement ($P < 0.0001$; Figure 2-2). During the heat of the day, all cattle came to water regardless of treatment, but supplemented cattle left the riparian area earlier in the evening and stayed in the uplands longer during the morning. This suggests that they also spent more time grazing in the uplands since previous research in these pastures found that 73% of all grazing activity occurred daily between 0601 - 0900 and 1801 - 2100 (Porath et al., 2001). The increase in upland observations occurred even though the only water source was Milk Creek and these pastures were relatively small. If changes in distribution were documented in these relatively small pastures it is likely the response would be even stronger in larger pastures. Results suggest that strategic protein supplementation can alter distribution in riparian pastures in late summer in a manner similar to the altered utilization patterns when cattle were supplemented in upland range in the fall and early winter (Bailey and Welling, 1999; Bailey et al., 2001b).

Vegetation Utilization and Stubble Height

The utilization of vegetation types was influenced by the presence of supplement. Utilization of riparian grass was 7% lower (P = 0.003), utilization of greenline vegetation tended to be 12 % lower (P = 0.063), and utilization of upland vegetation was 8% higher (P = 0.025) in supplemented pastures compared to control pastures. There was no difference in utilization of riparian sedge/rush utilization in pastures with supplement as compared to those without supplements (Figure 2-3). Though there was 12% less utilization in the greenline area this difference was not significant. This was due to the smaller sample size of greenline measurements. The greenline is the area within 1 m of each side of the stream, therefore only 24 measurements available per year per pasture.

Likewise, riparian grass stubble heights were 5.5 cm higher (P = 0.006) and greenline stubbleheights were 5.46 cm higher (P = 0.006) in pastures with strategically placed supplement. Riparian sedge/rush and upland stubbleheights did not differ for supplemented and unsupplemented pastures (Figure 2-4).

DISCUSSION

The results of this study suggest that protein supplement provided in strategic locations to cattle grazing riparian pastures in late summer can effectively decrease the use of riparian habitat and reduce utilization of riparian vegetation. This tool could therefore provide an ecological incentive for riparian management and a potential animal performance benefit for cattle managers.

Ocular utilization and stubble height measurements were specifically selected because they are commonly used to quantify acceptable levels of forage utilization on public lands (Clary and Leninger, 2000; Winward, 2000) Although riparian areas account for a small portion of this land base, improper grazing of riparian plant communities can result in the potential loss of access to a much wider forage base. The US government is the single largest landowner in the 11 western states with 85% of theses lands grazed and all managed for multiple values (Gentner and Tanaka, 2002). These lands are an integral part of livestock production in the region and there is often no substitute for the resources they provide (Mosely et al., 1990).

Supplementation has several advantages as a riparian grazing management tool. It is an accepted livestock management practice that fits with herd management objectives. Supplementing in late summer when spring calving beef cows nutritional requirements may exceed forage quality resulted in improved cow performance providing a potential financial return to managers (Table 3, Chapter 3 in this Volume). Sustainable beef production in the semi-arid West must constantly adapt to dynamic nature of semi-arid/high elevation rangelands and the resulting seasonal changes in cattle body weight and condition. Since winter feed costs typically average one third to one half of gross revenues in these environments, it is imperative that managers monitor cow body condition and weight loss in late summer. Supplementation can be applied in a flexible and efficient manner with no large capital outlay, special tools, skills, or infrastructure required. It can be implemented quickly in response to rapidly developing concerns such as drought and can be modified easily in adaptive management scenarios.

There are many forms and types of supplement available that will provide protein and energy to cattle consuming low quality forage. The “ideal” supplement has been defined as the one that fits the cattle’s nutritional needs, is easy to handle and deliver to the cattle, and is the best economic value to purchase and feed (DelCurto et al., 2000). To decrease the amount of use in the riparian areas of mountain riparian pastures a supplement should be selected that is easily delivered in rough country, can be used over an extended time period and has a low risk for introducing noxious weeds. The body condition and reproductive status of the cattle and the forage quality should then be assessed and the most economical alternative chosen.

The ecological effects of strategic protein supplementation include shifts in diet compositions including a tendency toward reduced consumption of riparian shrubs and an increase in consumption of upland shrubs and sedges (Table 1; Chapter 3 of this Volume). Stubble height has been found to be an effective measure of the effect of grazing on the physiological health of the individual plant and the ability of the vegetation to provide streambank protection and to filter out and trap sediments when flooding occurs (Bennett and Troyer, 2004).

The beneficial effects of supplementation might be enhanced if it was applied in concert with other management techniques (Bailey, 2004; Howery et al., 1998). Techniques such as providing off stream water, shade, and salt are effective in altering cattle distribution especially and might work well applied in combinations designed to maximize the habitat quality of the entire pasture (DelCurto et al., 2005). For instance Bailey et al., (1999) documented an increase in supplement consumption with salt when compared to consumption without accompanying salt. An economic analysis of the costs and benefits of the practice is imperative. Future research should also examine the use of other forms of supplement, different levels of consumption, techniques to increase the uniformity of consumption among individuals in the herd, and different seasons of use, stocking rates, and combinations of this management technique with other riparian grazing management tools.

MANAGEMENT IMPLICATIONS

Strategic protein supplementation can help alleviate negative riparian vegetation impacts by decreasing use of the riparian area by grazing cattle in late summer. This new technology can be applied quickly and with little capital investment. This technology may be even more effective if applied in concert with other techniques(Bailey, 2004). Supplementation is an important component of achieving sustainable riparian grazing management that balances the ecological and economic needs of rangeland managers in the semi-arid west.

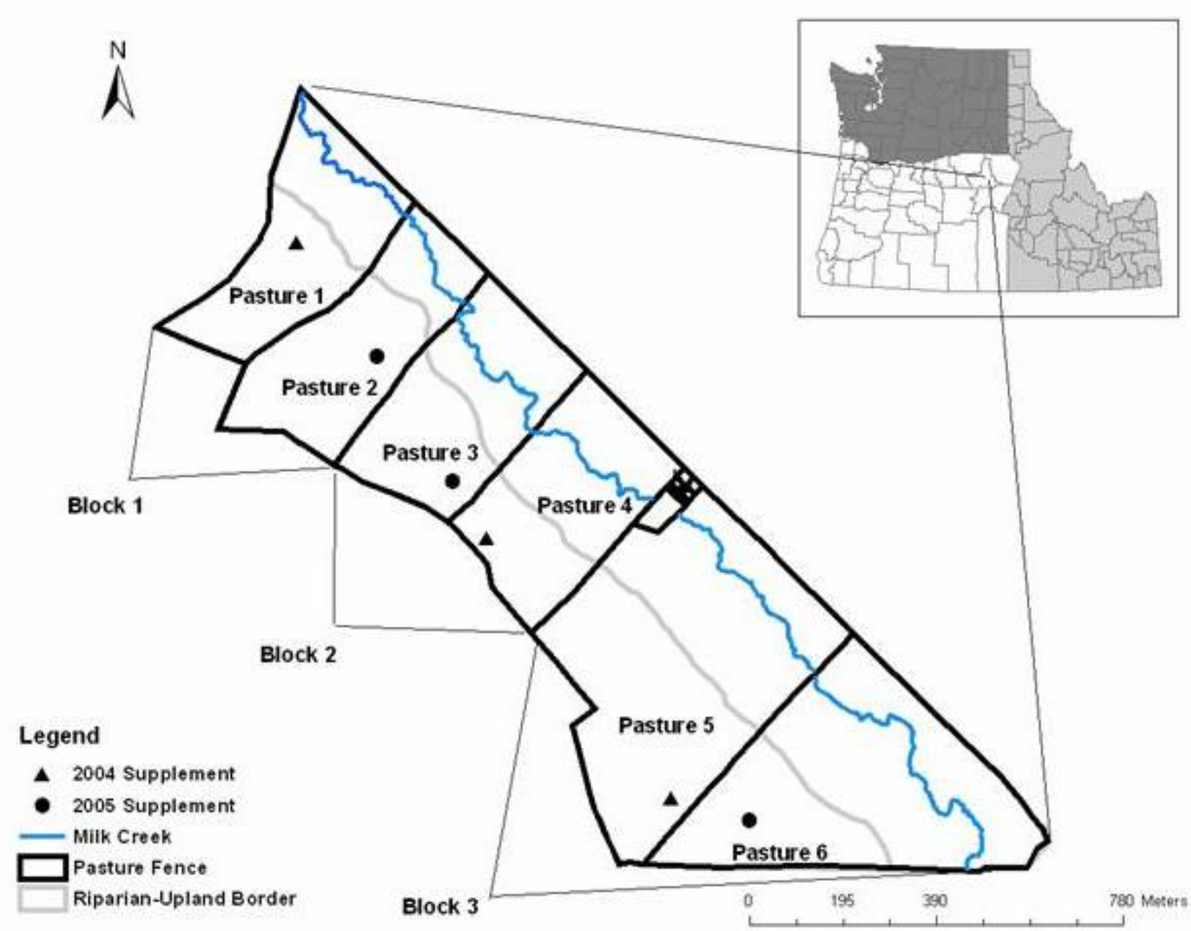

Figure 2-1. Milk Creek Study Site - Portion of Oregon State University's "Hall Ranch" utilized for the research project. Six pastures (averaging 13 ha for pastures 1-4 and 25 ha for pastures 5&6) were utilized to evaluate 2 treatments in 3 blocks. Data were collected in July and August of 2004 and 2005. Treatments include: 1) protein supplement (poured chemically hardened molasses 30% CP); 2) no protein supplement (control). Treatments in 2004 were randomly assigned as follows: Pastures 1, 4 and 5= protein supplement, Pastures 2, 3 and 6 control. Treatments in 2005 were reversed.

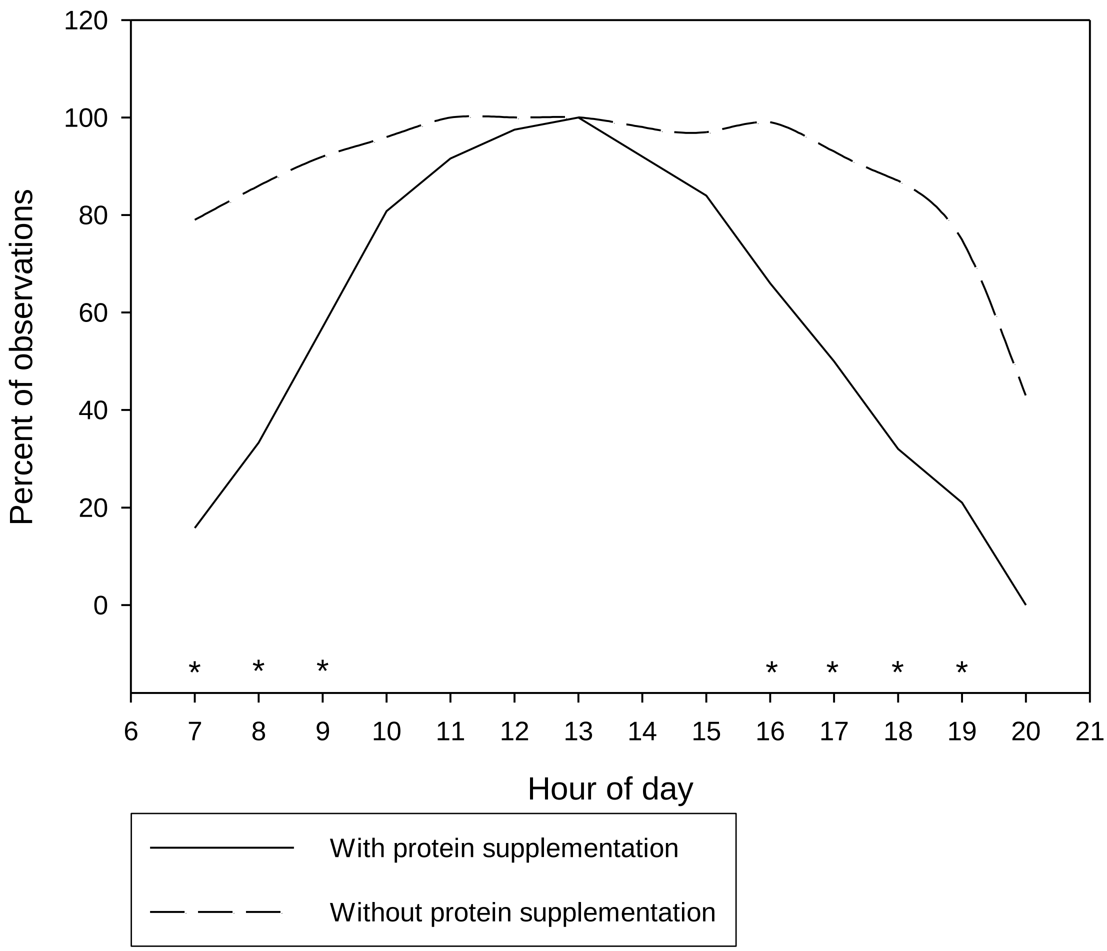

Figure 2-2. Effect of strategic supplementation on the percentage of cattle observations occurring in the riparian areas of pastures in northeastern Oregon throughout the day. Data were collected from day 21-24 of the study in July and August of 2004 and 2005. Values are averaged across days and years. Treatments include: 1) chemically hardened molasses protein supplement (30% crude protein with TiO_2 marker); and 2) no supplement (control). Values within a time period with an * differ at $P < 0.05$. The pooled SE for the measurements is 5.1%.

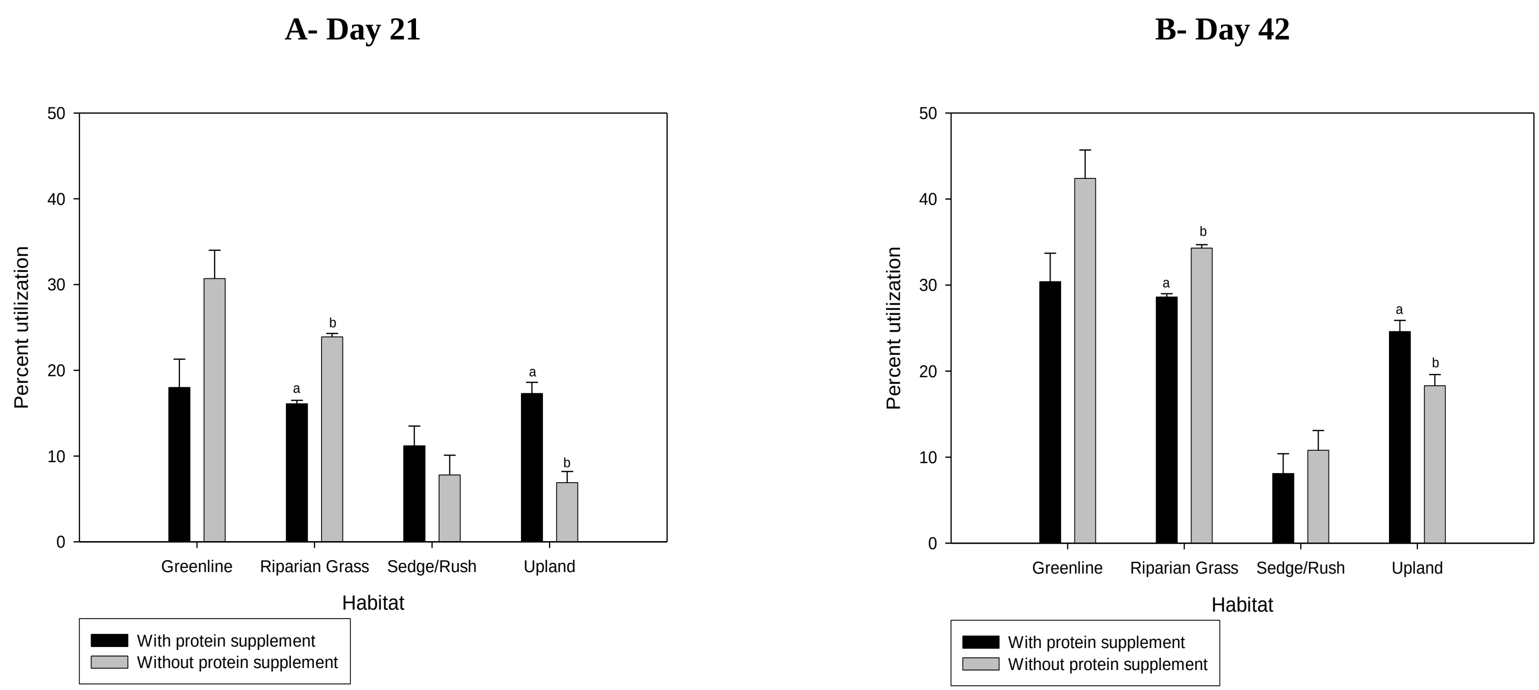

Figure 2-3: Effect of strategic protein supplementation on utilization of vegetation in pastures grazed by cattle along Milk Creek in northeastern Oregon. Treatments include: 1) chemically hardened molasses protein supplement (30% crude protein with TiO_2 marker); and 2) no supplement (control). Data were collected at a) day 21 and b) day 42 in July and August of 2004 and 2005. Values are averaged across years. Values with differing superscripts within a habitat type differ at $P < 0.05$. Bars represent the standard error of LS Means.

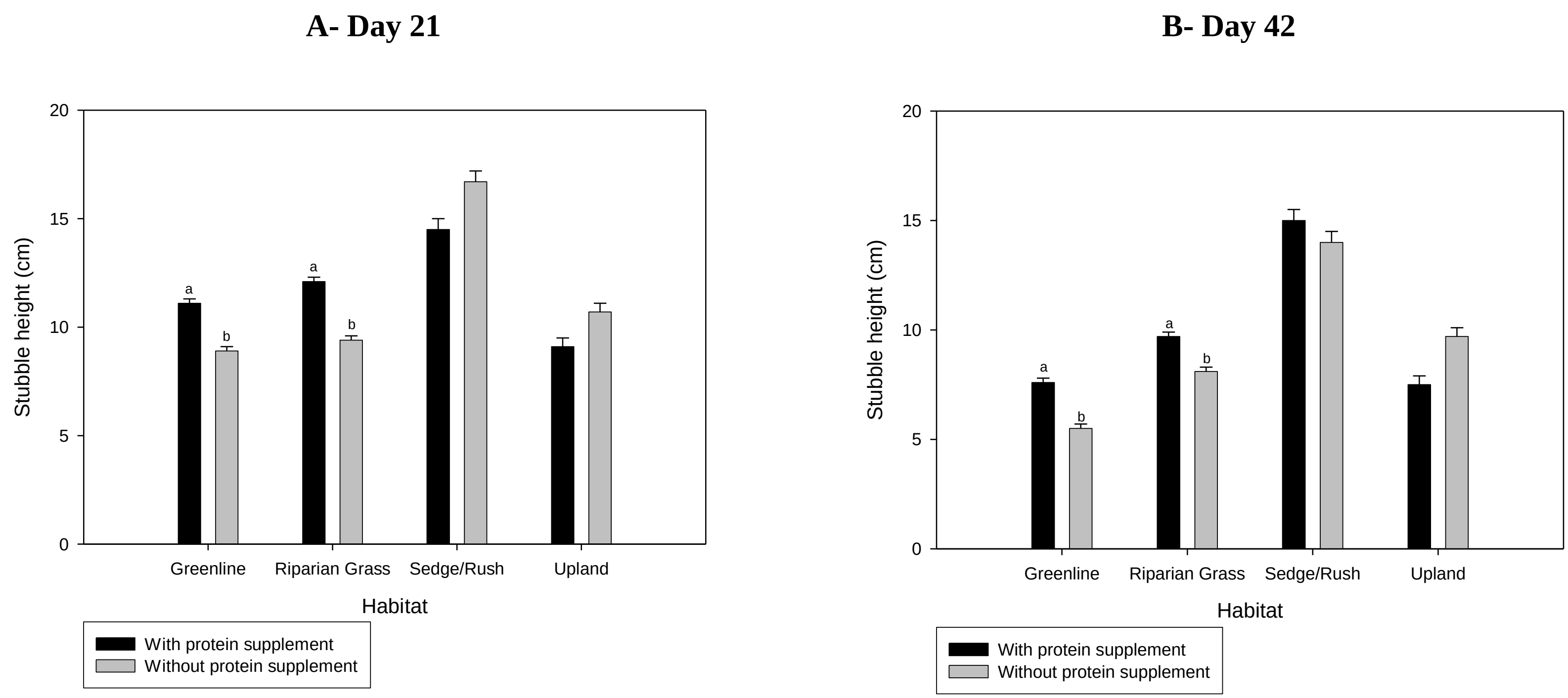

Figure 2-4. Effect of strategic protein supplementation on vegetation stubble height in pastures grazed by cattle along Milk Creek in northeastern Oregon. Treatments include: 1) chemically hardened molasses protein supplement (30% crude protein with TiO_2 marker); and 2) no supplement (control). Data were collected at a) day 21 and b) day 42 in July and August of 2004 and 2005. Values are averaged across years. Values with differing superscripts within a habitat type differ at $P < 0.05$. Bars represent the standard error of LS Means.

III. STRATEGIC PROTEIN SUPPLEMENTION EFFECT ON BEEF CATTLE PERFORMANCE AND DIET

ABSTRACT

This study was designed to quantify the effect of strategic protein supplementation on the performance and diet composition of cow/calf pairs grazing in mountain riparian areas in late summer. From 15 July to 27 August 2004 and 2005, the effect of strategic supplementation was assessed in two replicated experiments on separate riparian areas with (*n* = 3) and without (*n* = 2) uplands. Two treatments were randomly assigned to 1 pasture in each block. Treatments included: 1) chemically hardened molasses protein supplement (30% crude protein (CP) with TiO_2 marker) and 2) no supplement (control). In Milk Creek, riparian pastures with uplands, supplement was strategically placed in the uplands. In Catherine Creek, riparian pastures without uplands, supplement was placed in the riparian area. Stocking rates to achieve moderate utilization ranged from 0.6-1.2 AUM/ha. Cattle consumed supplement at the rate of 1.59 kg $pair^{-1}$ day^{-1} in riparian pastures with uplands and 2.1 kg $pair^{-1}$ day^{-1} in riparian pastures. Cows' consumption rates varied and were nearly two times calves' consumption rates on a per kilogram of body weight basis. While shrubs and forbs maintained the highest forage quality, cows continued to preferentially consume grasses and grasslikes regardless of supplementation. Overall diet composition was not influenced by supplementation ($P > 0.10$). Supplemented cows in riparian pastures with uplands gained an average of 12 kg more than un-supplemented cows ($P = 0.02$). Likewise, supplemented cows in riparian pastures without uplands tended to gain 13 kg more than un-supplemented cows ($P = 0.19$). Cow body condition score and calf average daily gain were not affected by strategic supplementation. Results suggest that strategic supplementation of cow/calf pairs in late summer does not conserve riparian vegetation by changing diet composition, but may improve cow performance providing a potential economic benefit to cattle producers.

KEYWORDS: grazing, beef cattle, riparian, protein supplementation, diet composition

INTRODUCTION

Protein is often the limiting nutrient in diets selected by cattle grazing dormant, low quality forages on rangelands in the western United States. When forage, such as grasses and grasslikes, senesce in late summer the balance of protein to energy is usually insufficient and cattle nutritional needs may exceed forage quality. Plants in riparian areas often senesce later, maintaining higher moisture content and crude protein (CP) level in late summer than the surrounding upland vegetation. This presents livestock producers with the dilemma of avoiding uneven distribution of livestock while providing adequate forage to achieve desired livestock performance.

Riparian areas are the assemblages of plant, animal, and aquatic communities whose presence can be either directly or indirectly attributed to factors that are water-induced or related (Kauffman and Kreuger, 1984). Although the geographic extent of riparian areas is limited, they display high levels of productivity and biodiversity (Naiman et al., 1993). Riparian vegetation provides many ecological functions including: diverse fish and wildlife habitat, sediment filtration, soil and streambank stabilization, regulation of water temperature, nutrient cycling, and aquatic and riparian food web support (National Research Council, 2002; Powell et al., 2000). The higher quality and quantity of the forage found in riparian areas also makes them economically important to livestock production in the Pacific Northwest (DelCurto et al., 2005). The ecological and economic importance of riparian areas emphasizes the need for management strategies to meet diverse objectives.

The impacts of cattle grazing on riparian areas are complex and varied, but concerns usually arise from uneven grazing distribution (Bailey, 2004; DelCurto et al., 2005; Fleischner, 1994). Cattle tend to disproportionately use riparian areas compared to adjacent uplands (Parsons et al., 2003; Smith et al., 1992a). Many studies and observations have reported that improper grazing of riparian vegetation has negative impacts on riparian and aquatic ecosystems (Belsky et al., 1999; Fleischner, 1994; Kauffman et al., 1997). These impacts include: increased soil erosion, decreased bank stability, reduced water quality, net loss of water storage, and decreases in plant and animal habitat quality resulting in decreased biodiversity and productivity (DelCurto et al., 2005; Powell et al., 2000).

Grazing distribution becomes increasingly spatially uneven during late summer. This has been documented consistently in the Intermountain and Pacific Northwest regions with studies across ownerships and regions in the western US finding that in late summer cattle spent a disproportionate amount of their feeding time in the riparian zone (Elmore and Kovalchik, 1991; Pogacnik and Marlow, 1986; Smith et al., 1992a, 1992b). Uneven late summer grazing distribution has also been documented specifically at the study site in this report on Milk Creek. Researchers at the Eastern Oregon Agricultural Research Center (EOARC) in northeastern Oregon have documented in a series of studies that as forage quality and quantity declines, cattle display a disproportionate preference for riparian vegetation (Darambazar et al., 2003; Morrison et al., 2002; Parsons et al., 2003; Porath et al., 2001; Vavra and Phillips, 1979).

Riparian grazing management strategies that decrease use of the riparian areas by livestock in order to maintain or improve the condition of the riparian vegetation are imperative to ensure the sustainability of livestock grazing (DelCurto et al., 2005). Public lands are managed for multiple objectives and must comply with numerous policies and laws such as the 1973 Endangered Species Act and 1973 Clean Water Act. Livestock grazing management strategies to alter livestock distribution and vegetation utilization have been studied throughout the Intermountain West and Pacific Northwest region. These include: water development, changes in stocking rate, altering season of use, selecting grazing animals by age, breed, reproductive status or individual characteristics, providing shade, burning, fertilizing, fencing for exclusion or concentration of cattle, herding, and strategic supplementation (Bailey, 2004; DelCurto et al., 2005).

The list of techniques with potential for achieving altering grazing distribution of cattle is long and varied, but few also address the needs of producers to maintain the performance of their livestock. Strategic protein supplementation is a technique that may address both performance and distribution concerns. Protein supplementation (beginning when the upland forages lose nutritional quality and ending when the shrubs shed their leaves) may improve grazing distribution with minimal effort and low cost. Ares (1953) documented a 50% decrease in areas of excessive cattle use (as defined in his protocol) when a cottonseed meal-salt supplement was strategically placed on rangeland in the southwest. A similar study in the southwestern US provided strategically placed block salt with and without meal-salt, but found there was just a trend toward more uniform distribution (Martin and Ward, 1973). Strategic placement of protein supplement resulted in a 13 to 72% increase of residual dry matter in the riparian areas of hardwood rangeland in California (McDougal et al., 1989). Bailey and Welling (2001) found that cattle grazing northern Montana rangelands in fall and early winter spent more time and grazed more in areas where supplement was strategically placed including increased use of areas that were steeper and/or at greater distances from water. Bailey et al., (2001b) also measured increasing forage use up to 600 m from strategically placed supplement on northern Montana rangelands in early fall, late fall and early winter. Another study measured the use of low moisture molasses block (LMB) and conventional dry mineral mix (CDM) by cattle grazing Montana rangeland. Cattle visited the LMB more consistently suggesting that LMB has higher potential to modify grazing distribution than CDM especially when placed off stream and in rough terrain (Bailey and Welling, 2007).

Dormant rangeland forage is often high in fiber and deficient in both protein and energy for lactating cows in late summer. The primary goal of forage-based livestock production systems is to obtain maximum animal performance while effectively utilizing the forage resource base. When the availability of high-quality forage is limiting, supplements can result in improved animal performance and more uniform utilization of rangeland forage (Kincheloe, 2004). Supplementation is an accepted livestock management practice that fits with herd management objectives. Supplementing in late summer when spring calving beef cows nutritional requirements may exceed forage quality can improve cow performance providing a potential financial return to managers. Sustainable beef production in the semi-arid West must constantly adapt to dynamic nature of semi-arid/high elevation rangelands and the resulting seasonal changes in cattle body weight and condition. Since winter-feed costs are often the greatest expense in these environments, managers should monitor cow body condition and weight loss closely in late summer. A cow in good condition is easier and less costly to feed through the winter and has fewer problems with subsequent calving and rebreeding potential (DelCurto et al., 2000).

Riparian area ecological and economic values, public pressure, and legal restrictions create a pressing need for continuing research on practical and economically viable strategies for riparian grazing management that emphasizes improved cattle distribution. Strategic protein supplementation is one such management strategy. While this appears to be a reasonable management option, there is limited published research available that quantifies the effect of strategically placed protein supplement on cattle performance and diet selection in riparian pastures. Therefore this research project seeks to provide a replicated, quantitative assessment of the effect of strategic protein supplementation on the performance and diet composition of cattle grazing mountain riparian pastures in late summer.

METHODS

Study Site

This study was conducted on Oregon State University's Eastern Oregon Agricultural Research Center's "Hall Ranch" located in the foothills of the Wallowa Mountains in northeastern Oregon (lat 45°7'48"N, long 117°42'32"W). Elevation averages1015 m. Average annual precipitation is 35 cm with over 60% occurring as snow during the winter months. Total July and August rainfall averages 3.94 cm and average July and August evaporation totals 35.38 cm (Taylor et al., 1993). The climate includes cold, snowy winters and hot, dry summers that provide limited potential for vegetative re-growth July through September.

The Hall Ranch includes two distinct riparian zones. Catherine Creek, the larger stream, is a third order tributary of the Grande Ronde River. Milk Creek, a smaller stream, is a tributary of Catherine Creek. This area contains a mosaic of tree, shrub, meadow, and aquatic plant communities. The grazing history of Milk Creek and Catherine Creek are similar. From 1940 to the 1960's the area was unfenced and continuously grazed through out the season. From 1962 to 1977 interior fencing was constructed and these pastures were used as spring breeding pastures in May and grazed again in the fall. From 1978 the site has been grazed for 3-4 weeks beginning in late August at a stocking rate of 1.3-1.8 AUM/ha (Beschta et al., 1995).

This basin provides both spawning and rearing habitats for resident and anadromous fish species. Three species, the Snake River steelhead (*Oncorhynchus mykiss gairdneri*), Snake River spring/summer chinook (*Oncorhynchus tshawytscha*) and bull trout (*Salvelinus confluentus*) are federally listed as threatened by the US Fish and Wildlife Service (Trask, 2001).

Within each pasture the vegetation was classified into three vegetation types: riparian grass, riparian sedge/rush, and upland. Plant species composition previously collected on the study site by Porath et al., (2001) was used to classify vegetation communities and estimate production.

Riparian grass communities are those that inhabit the active floodplain and consist of > 50% grasses by weight. Grass species included Kentucky bluegrass (*Poa pratensis*), meadow foxtail (*Alopecurus* pratensis), redtop (*Agrostis alba),* timothy (*Phleum pretense*), and brome (*Bromus* spp.). Sedges (*Carex* spp.) and rushes (*Juncus* spp.) and numerous forbs including tall buttercup (*Ranunculus acris*), northwest cinquefoil (*Potentilla gracilis*), red clover (*Trifolium pretense),* stream bank butterweed (*Senecio pseudaureus*), fleabanes (*Erig-eron* spp.), western yarrow (*Achillea millefolium*), and lupines (*Lupinus* spp.) were also pre-sent. The dominant woody species include Douglas' hawthorne (*Crataegus douglasii),* thinleaf alder (*Alnus incana*), common snowberry (*Symphoricarpos albus*), Mackenzie wil-low (*Salix rigida*), wild rose (*Rosa woodsii*), and ponderosa pine (*Pinus ponderosa*) and black cottonwood (*Populus trichocarpa*).

Riparian sedge/rush communities are located in the active floodplain as well, but are distinctive due to the presence of > 50% sedge and/or rush species by weight. Other species present are the same as the riparian grass community.

Upland communities are those present outside the active floodplain and are typically dominated by grasses. These include timothy (*Phleum pretense*), orchard grass (*Dactylus glomerata*), needlegrass (*Stipa* spp.), bromes (*Bromus* spp.), Idaho fescue (*Festuca idahoensis),* Kentucky bluegrass (*Poa pratensis*), pinegrass (*Calamgrostis rubescens*), elk sedge (*Carex geyeri*), a variety of forbs, and patches of shrubs including common snowberry (*Symphoricarpos albus*), spirea (*Spirea splendens*), and ceanothus (*Ceanothus* spp.). The uplands have an over story of ponderosa pine (*Pinus ponderosa)* interspersed with open meadows.

Protein supplement was provided in the form of a chemically hardened molasses block with 30% crude protein (CP) packaged in a 100 kg tub. The supplement consisted of molasses products and the predominant protein sources were 18% plant products (soybean meal, canola meal and urea) and 12% non-protein nitrogen (urea). The supplement was formulated for an expected consumption rate of 1 kg pair^{-1} day^{-1}. Less than 1% of an indigestible white powder, titanium dioxide (TiO_2) was added as a marker to the supplement for use in fecal analysis (Meyers et al., 2004). Supplemental protein was provided *ad libitum* and was checked on a regular basis. To ensure familiarity with the supplement, cattle were given access to the supplement for a month during the winter feeding period. Loose mineral salt was provided *ad libitum* in supplement and control pastures each year at the supplement sites.

Milk Creek

The study incorporated approximately 109 ha of riparian meadow and adjacent uplands bordering Milk Creek, a narrow, low gradient, perennial, spring fed stream. The study site was stratified into three blocks based on vegetation type. Blocks were cross-fenced with electric fence to create six pastures (n = 3); (Figure 3-1). Four pastures were approximately 13 ha and 2 were 25 ha. Pasture size was based on the average vegetation production per hectare in order to obtain a uniform utilization level at a set stocking rate between all pastures (Porath et al., 2001). Pastures five and six were larger to compensate for lower production due to a dense overstory canopy and a smaller riparian area.

These six riparian pastures with uplands were used over a two-year period in a 2x2 cross-over design (Steele and Torrie, 1980) within three blocks of the following two treatments: 1) chemically hardened molasses protein supplement (30% crude protein (CP) with TiO_2 marker) and 2) no supplement (control). Each treatment was randomly assigned to one pasture within each of the 3 blocks. In mid-July of each year, sixty cow/calf pairs (angus-cross, avg. wt = 533 kg, SE = 14 kg) were stratified by age and randomly assigned to the 6 pastures. Pastures were stocked with 10 pair to achieve moderate utilization from July 15 to August 27 (42 days). Stocking rates were 1.2 AUM/ha in the 13 ha pastures and 0.6 AUM/ha in the 25 ha pastures. Milk Creek, a perennial stream flowing through each of the pastures, was the only water source for livestock grazing the pastures. Supplement was strategically placed in upland locations averaging 267 m from the stream in an attempt to alter distribution and vegetation utilization.

Catherine Creek

The study incorporated 45 ha of riparian meadow bordering Catherine Creek, a perennial stream with a meandering, braided channel confined by steep hills on the east and by state highway on the west. The downstream portion of the site is an open grassland and the upper portion has greater shrub and tree cover (Laliberte et al., 2001). Five exclosures established in 1978 (Kauffman et al., 1983b) were also included in the study site. The exclosures span the stream and alternate with grazed areas so that the linear run of the stream is divided nearly equally into exclosed and grazed sites.

The study site was stratified into two blocks based on vegetation type. Blocks were cross-fenced with electric fence to create four 11 ha pastures (*n* = 2 per block; Figure 3-2.). Four riparian pastures were used over a two year period in a 2x2 cross-over design (Steele and Torrie, 1980) with two blocks of the following two treatments: 1) chemically hardened molasses protein supplement (30% CP with TiO_2 marker) and 2) no supplement (control). Each treatment was randomly assigned to one pasture within each of the blocks in 2004 and then the alternate treatment was applied that specified pasture in 2005. In mid-July of each year, 32 cow/calf pairs were stratified by age (angus cross, avg. wt = 523 kg, SE = 26 kg) and randomly assigned to the 4 pastures. This resulted in pastures that were stocked with 8 pair each from July 15 to August 27). Stocking rates were 0.9 AUM/ha to achieve moderate utilization. Although the study was designed to be a 42 day study, drought induced limitations to forage production required that the study be shortened to 35 days in year two of the study (2005). Catherine Creek was the only water source for livestock grazing the pastures. Because the Catherine Creek pastures were confined to riparian areas, supplement was placed in the riparian zone in a manner that minimized impact on streambanks and fish habitat.

Supplement Consumption

Total supplement consumption per pasture was assessed by weighing each tub of supplement delivered to each pasture, subtracting an average container weight and weighing out any remnants at the close of the study. . Four consecutive days of fecal collections were made from 4-5 cows and 4-5 calves randomly selected in each replication from day 21-24 in each year of the study. Large numbers were painted on the side of each cow to facilitate identification. The samples were dried in a forced air oven at 50° C for at least 72 hours. Samples from all four days were combined into one composite sample per animal. Then samples from each pasture were combined into one sample for cows and one sample for calves for each year. An analysis of the relative percent TiO_2 in fecal dry matter (FDM) samples was used to assess variation in supplement intake (Meyers et al., 2004; Titgemeyer et al., 2001).

Forage Quality

Twenty-three major forage species including 15 grasses and grasslikes, 4 forbs and 4 shrubs commonly occurring in the study area were chosen for sampling to evaluate forage nutritive quality. For each plant species a composite sample of about 40 g (dry weight) was collected at random locations throughout their respective distributions in the study area by hand plucking to simulate grazing. The samples were then oven dried at 50° C and analyzed for CP using a Kjeldahl technique (Association of Analytical Chemists, 1990), neutral detergent fiber (NDF) and acid detergent fiber (ADF) using a filter bag method developed by ANKOM Technology Corporation (1997) and in vitro dry matter digestibility (IVDMD (Tilley and Terry, 1963). All data on nutritive quality are reported on a dry matter basis.

Diet Composition

The composited fecal samples collected from the cows and calves in each pasture were also used to assess diet composition. The botanical composition of the diet was determined by microhistological examination by modifying existing frequency-density conversion sampling procedures of research methods described in four studies (Flinders and Hansen, 1972; Holechek and Goss, 1982; Sparks and Malechek, 1968; Vavra and Holechek, 1980). Relative cover (Davitt, 1979; Korfhage, 1974) of plant cuticle and epidermal fragments were quantified for 25 randomly located microscope views on each of four slides (total 100 views). A ten by ten-square grid mounted in the eyepiece of the microscope was used to measure area covered by each positively identified fragment observed at 100x magnification. Larger magnification is used (200x to 450x) to aid in the identification of discernable fragments (Holechek and Valdez, 1985). Measurements of area covered were recorded by plant species, genus or forage class category as desired. Percent diet composition was calculated by dividing cover of each plant by total cover observed for all species, then multiplying by 100. Analysis identified the major forage classes and the 6-10 major forage species found in the diet. This allowed the relative percentage of the grasses, grasslikes, forbs, shrubs and other (bark, soil, pine needles, moss, etc.) to be calculated.

Cattle Performance

Cow weight change, body condition score change and calf average daily gain (ADG) during the trial were used to assess cattle performance. Prior to weighing and condition scoring, all cattle were placed in a dry lot overnight without access to feed or water to limit the effects of rumen fill on measurements taken. Body condition scoring is a method of categorizing cows according to the amount of body fat reserves. Apparent external fat cover, muscle appearance, and skeletal features are considered in order to assign a condition score which is correlated to the animal’s relative body fatness (Momont and Pruitt, 1999). Condition scores were assigned on a scale of 1-9 (1= extremely emaciated, 9= very obese). Because the condition scoring method is inherently subjective, the average score from two independent observers was assigned to each cow and averaged.

Statistical Analysis

Data were analyzed separately for experiments on Catherine Creek and Milk Creek. Data were analyzed using GLM procedures of SAS (SAS, 1996) as a two treatment, replicated, cross-over design. Pasture was the experimental unit and supplement was the treatment. Data such as diet composition, supplement consumption, TiO_2 concentrations and performance measures collected on individual animals within a pasture were compiled into an average measurement per pasture for that treatment. Means were separated using least square means procedure of SAS and were considered significantly different at the ($P < 0.05$) level.

RESULTS

Supplement Consumption

Cow/calf pairs grazing riparian pasture with uplands consumed an average of 1.59 kg $pair^{-1}$ day^{-1} of supplement in 2004 and 2005. Cow/calf pairs grazing riparian pastures without uplands consumed an average of 2.15 kg $pair^{-1}$ day^{-1} in 2004 and 2005. Consumption rates of cow calf pairs grazing riparian pasture with uplands were 50% higher than projected and consumption rates of cow/calf pairs grazing riparian pastures without uplands were twice the predicted rate. An analysis of the percentage of TiO_2 in FDM in samples from 24 cows and 24 calves suggested that consumption rate did not vary between pastures, but did vary among individual cows and between cows and calves (Figure 3-3). The cows averaged 0.0005% TiO_2 per kilogram body weight while the calves averaged 0.0002% TiO_2 per kilogram body weight suggesting that cows consumed more than twice as much supplement as calves.

Forage Quality

Forage quality was similar between experiments both years. Grass and grasslike forages of both experiments with protein levels averaging only 4-8% would be considered deficient for gestating, lactating cows six months after calving that require 7.92% crude protein (National Research Council, 1996). Shrubs and forbs are higher quality at this time of year with crude protein levels of 9-18% (Table 1). Calves weighing 300 pounds and gaining 1.75

pounds per day require over 14% CP and if milk production has declined enough due to waning forage quality they might also be protein deficient (National Research Council, 1996). Therefore, we hypothesized that consumption of a protein supplement would improve the performance of cows and calves.

Diet Composition

Microhistological analysis of fecal samples suggests that grasses were the largest component of cow and calf diets across all pastures and treatments ranging from 49-69% (Table 2). Grasslikes were the second largest diet component ranging from 18-41%. Forbs were 6-12% and shrubs were 0.5-7% of the diet of cows and calves grazing mountain riparian pastures in late summer. While shrubs and forbs maintained the highest forage quality (Table 1), cattle continued to preferentially consume grasses and grasslikes and diet composition was not influenced by supplementation (*P* > 0.10).

Supplemented cows in riparian pastures without uplands tended to consume more elk sedge (*Carex geyeri)* than un-supplemented cows (*P* = 0.08). In riparian pastures with uplands there was a tendency for supplemented cows to consume more of the shrub, common snowberry, (*Symphoricarpos albus)* than un-supplemented cows (*P* = 0.06).

Performance

In Milk Creek's riparian pastures with uplands, supplemented cows gained more weight than un-supplemented cows (*P* = 0.02). In Catherine Creek, riparian pastures without uplands, supplemented cows tended to gain an average of 12.91 kg more than those without supplement. In contrast, calf performance did not improve when protein supplement was offered. Calf average daily gains were 1 kg and did not change with supplementation. Cow body condition scores were not affected by protein supplementation.

DISCUSSION

Supplement Consumption

To maximize effectiveness of a supplementation program, each animal must consume the target amount of supplement to ensure desired nutrient intake of nutrient, vitamin, or mineral. Individual supplement intake may vary with animal preferences, supplement palatability and formulation, delivery method, social interactions, and forage availability (Bowman and Sowell, 1996). High levels of variation in the percentage of TiO_2 in FDM between cattle suggested that consumption varied among individuals (Figure 3-3). Consumption rates of cow/calf pairs grazing riparian pasture with uplands were 50% higher than projected and consumption rates of cow/calf pairs grazing riparian pastures without uplands were twice the predicted rate. The elevated intake rates and high level of variability may have been due to the mixed age classes of the herd, the form of the supplement and the delivery method.

Cows ranging from two to six years old were combined in mixed age herds during this study. Hierarchies are known to exist in cattle herds as observed by Bowman and Sowell (1997) where dominant animals often consume large amounts of supplement and prevent other animals from consuming their share. Kincheloe (2004) investigated the effects of herd size on supplement intake by a mixed age group of cows and found that cow age consistently affected supplement intake, with younger cows consuming the least amount of supplement compared to older cows and as a result, gained the least amount of weight. The high levels of variation and over consumption of supplement may have come from the inability of younger cattle to consume the target amount of supplement and the opportunity for older cows to over consume due to the social interactions of the mixed age herd.

While variation in individual supplement intake exists regardless of supplement form, studies have found that self-fed blocks are often characterized by uneven consumption rates. Garossino et al. (2003) evaluated differences in feeding behavior and supplement intake between animals consuming self-fed molasses blocks and liquid molasses supplement. They found larger variation in supplement intake with blocks, though neither supplement resulted in achieving target intake levels.

The delivery method chosen for the supplementation in this study, self-fed chemically hardened molasses tubs was chosen for ease of delivery, but may have contributed to the high levels of variability and over consumption of supplement. A review of 20 supplement studies by Bowman and Sowell (1997) reported higher variation for self-fed supplements across a range of animals, environments, and supplement formulations. The advantages of self-fed supplements are that they have the potential to modify grazing distribution and activity of cattle and decrease supplementation delivery costs. In a review of studies investigating the influence of supplementation on grazing behavior, Krysl and Hess (1993) reported that cattle supplemented with protein, grazed about 1.5 hour/day less than un-supplemented cattle. Other research suggests that cattle can be attracted to underutilized areas of pastures by providing supplements in those areas. Bailey and Welling (1999) found that forage utilization by cattle grazing foothill rangelands was increased by about 17% through strategic placement of dehydrated molasses supplement blocks compared to control areas. In addition, self-fed supplements can be delivered infrequently, which can reduce labor and transportation costs (Sawyer and Mathis, 2000). If the primary goal is to conserve riparian vegetation, variation in consumption rate and performance response may be acceptable. However, over consumption means higher costs with no additional performance benefit since cattle cannot efficiently use protein consumed in excess of requirements (Bowman and Sowell, 1996).

Calves consumed very small amounts of supplement across all pastures in our study. The percentage of TiO_2 in FDM for cows was nearly two times as much as the amount in calves when calculated on a per kilogram body weight basis. While numerous studies have researched ways to economically supplement nursing calves on pasture, the first limiting nutrient of nursing calves has not been well documented. Some studies found that gain was limited by energy (Faulkner et al., 1994) while others found that un-degradable intake protein was the first limiting nutrient (Hollingsworth, 1994). Supplementation of nursing beef calves, or “creep feeding,” has been found to increase summer weight gain and feedlot gain, but the supplemental feed efficiencies have been relatively poor requiring more than 8 kg of supplemental feed to produce a kilogram of gain (Stricker et al., 1979). North Dakota State University researchers supplemented nursing calves grazing native range at three protein levels and saw no effect on forage or milk intake and no differences in calf gain (Loy et al., 2002). Because the supplements were similar in energy content the authors suggested that energy was the first limiting nutrient for weight gain of nursing calves grazing native ranges.

Forage Quality

While forage quality did not differ by year, forage quantity decreased in year two of the study in the riparian pastures of Catherine Creek. Precipitation records suggest that unseasonably hot and dry conditions in late summer may have accounted for this difference. The forage quality of individual species varied by habitat with riparian species displaying the higher quality overall. This suggests an explanation for the preferential selection of this habitat unless an attractant alters the grazing distribution pattern.

Diet Composition

Diet composition was not influenced by supplementation, but cows with access to supplement displayed a tendency to make subtle shifts in their diet composition when the treatment was being applied. Cattle diets were dominated by grasses and grasslikes with shrub consumption was low across all treatments averaging from 2-7%. Supplemented cows in riparian pastures with uplands did show a tendency to increase consumption of common snowberry (*Symphoricarpos albus).* This may have been because of their ability to alter grazing patterns in response to forage availability. Grazing animals have behavioral patterns of foraging. These patterns lead to grazing animals forming preferences and aversions for specific locations in their environment (Launchbaugh and Howery, 2005). A review of supplementation strategies described the ability of different types of supplement to enhance desired foraging behaviors and increase foraging efficiency (Huston et al., 1999). In pastures where supplement was provided in the uplands, distribution changes may have altered forage availability and allowed cows to change their diet based on forage availability. Supplemented cattle showed a preference for the uplands (Figure 2-2) during their peak foraging hours suggesting that the increase may have reflected availability due to distribution changes. Studies that track cattle foraging movements suggest that cattle appear to have the ability to track the level of forage availability in plant communities and also to associate those availabilities with their location and adjust their behavior to make better use of these resources (Bailey et al., 1990).

Supplemented cows in riparian pastures without uplands tended to consume more elk sedge (*Carex geyeri)* perhaps in an effort to increase foraging efficiency. Many models that attempt to explain foraging behavior are premised on energy maximization, but there is limited empirical evidence for this (Bergman et al., 2001). The major constraints on forage intake are quality and availability. Canadian researchers offered wood bison a mosaic of grazing patches that varied in quality and quantity of forage. The bison chose to minimize their foraging time by selecting the patches with greater biomass regardless of quality. Researchers hypothesized that they were behaving as time minimizers since their foraging competed with other activities which contribute to overall fitness (Bergman et al., 2001). Results from previous studies have suggested that protein supplementation improves forage intake and digestibility of lower quality forage by increasing microbial growth, fermentation, and rates of passage allowing lower quality forage to be more effectively digested (Kincheloe, 2004). Perhaps supplemented cows were better able to digest and utilize the higher biomass, lower quality elk sedge communities. This would tend to minimize their foraging time while still meeting their nutritional needs thereby increasing their foraging efficiency and overall fitness.

Calf diets did not change with supplementation. However, calf diets were more varied than cow diets containing a higher percentage of forbs and shrubs. A calf's diet throughout its first year is a complex relationship between the quantity and quality of available forage, the calf's stage of growth and digestive development, and learned behaviors. Studies have found that calves appear to select higher quality forage than cows with their diets being higher in crude protein than cows (Ansotegui et al., 1988). At weaning, milk still provides 19% of daily energy requirements of calves (Bailey and Lawson, 1981). This suggests that nutrients provided by the mother's milk may allow the calf to be a more selective forager.

Performance

Supplemented cows gained more weight in pastures with and without uplands, but the weight gain was not expressed uniformly. It is not unusual for lactating cows grazing rangeland in late summer to lose weight and decrease body condition. The positive effects of protein supplementation for cattle consuming low quality forages are well documented, and include improvements in cow weight, body condition score, forage intake and digestibility, and pregnancy rates (Kunkle et al., 1999). With consumption rates higher than projected and varying between individuals, the resulting performance response was highly variable. The more uniform response in pastures with uplands was probably related to the distribution changes and the propensity of supplemented cattle to spend peak foraging time in the uplands where larger volumes of dormant grasses and upland shrubs such as common snowberry were available for browsing (Figure 2-2).

Improved cow performance and protein supplementation may have other beneficial effects. A review of the literature concluded that inadequate precalving and (or) post calving energy or protein nutrition lowers pregnancy rates and first service conception rates and increases the length of the postpartum interval in beef cows (Randel, 1990). Other more recent studies using beef cows have drawn similar conclusions. Beef cows grazing native winter and spring rangeland, were supplemented with protein to determine effects of supplementation on nutrient status and subsequent calf and reproductive performance. Protein decreased weight loss and shortened the interval from calving to first estrus, but did not improve calf performance or conception rate (Dhuyvetter et al., 1993). A three year experiment evaluated the influence of supplemental protein prepartum on pregnancy rates and calf feedlot performance. Feeding supplement prepartum improved cow BCS and increased the percentage of live calves at weaning, but did not affect pregnancy rate. Calves born to dams fed supplement prepartum had similar birth weight, but greater weaning weight. However, steer feedlot performance was not affected. Increased percentage of live calves increased net returns at weaning and after finishing in the feedlot (Stalker et al., 2006).

Calf ADG was not influenced by supplementation. This was probably because of low intake levels. Calves in a previous study showed a very low and variable intake of a similar self-fed molasses supplement (Suverly, 1999). Therefore, the benefit of supplementation in this study is limited to influence on cow distribution and performance.

MANAGEMENT IMPLICATIONS

Strategic protein supplementation can improve cattle performance in late summer providing a potential economic benefit to producers. Avoiding weight loss in cows in late summer has been shown to influence calving ease and rebreeding rates as well as providing a direct economic benefit through the increased weight of cull cows (Lamb et al., 1997). However, the effects on diet composition were minimal.

Future research should include an economic analysis of the costs and benefits of the technique. This would provide a valuation of the less tangible benefits such as improving the ecological sustainability of riparian grazing systems and improving herd reproductive health and vigor. Different target consumption levels, delivery methods and types of supplement could be explored to help determine if this technique could be implemented more economically. More detailed diet composition work may be needed to detect changes in the amount of riparian shrubs consumed since they make up such a small portion of the diet in general. Results suggest that supplementation is an important tool that producers can use to achieve sustainable riparian grazing management.

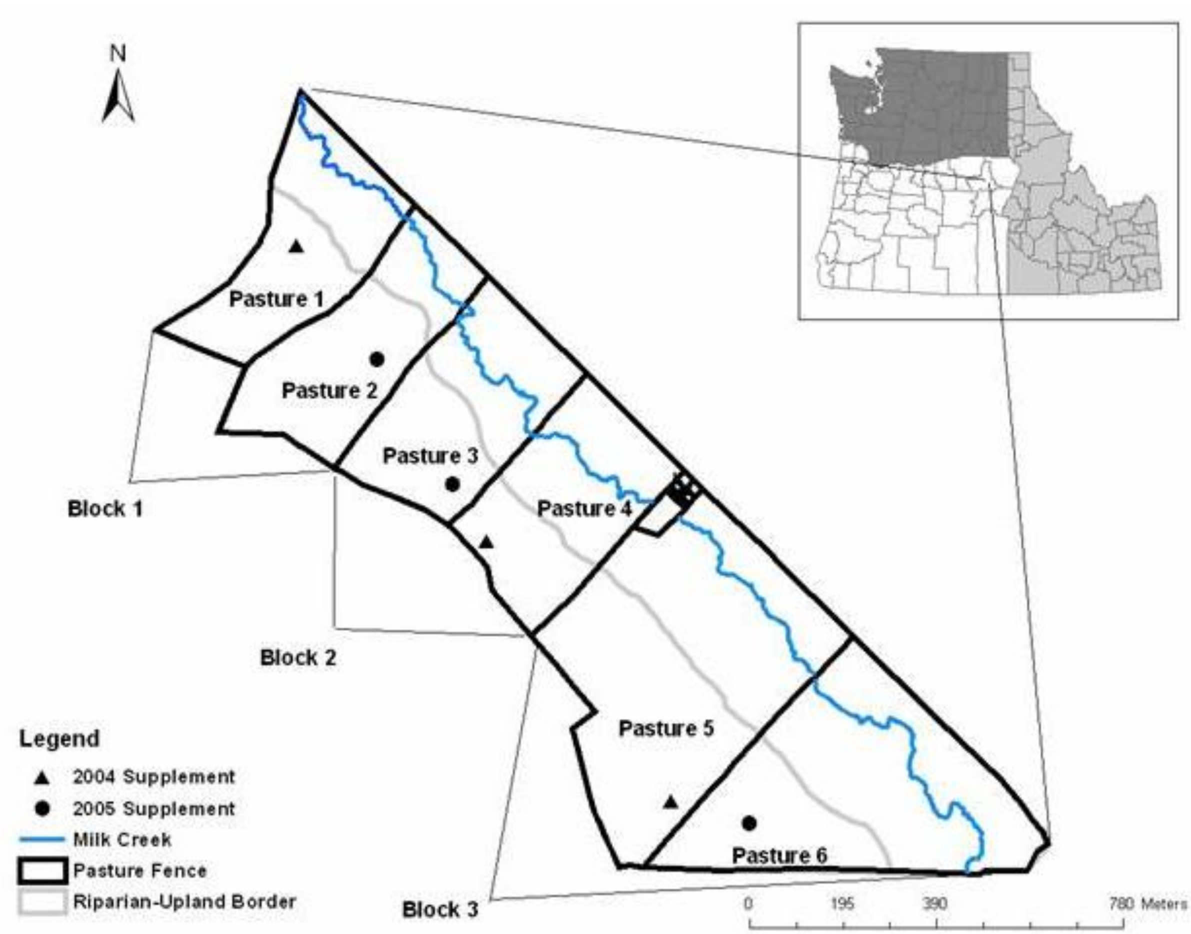

Figure 3-1. Milk Creek Study Site - Portion of Oregon State University's Hall Ranch utilized for the research project. Six pastures (averaging 13 ha for pastures 1-4 and 25 ha for pastures 5 and 6) and a 2,340 m stretch of Milk Creek were utilized to evaluate the effect of protein supplement on riparian vegetation utilization. All pastures have riparian stream, riparian meadow and adjacent uplands. Treatments in 2004 (Year 1) were randomly assigned as follows: Pastures 1, 4 and 5= upland protein supplement, Pastures 2, 3 and 6 no supplement. Treatment assignments for 2005 (Year2) were reversed from Year 1.

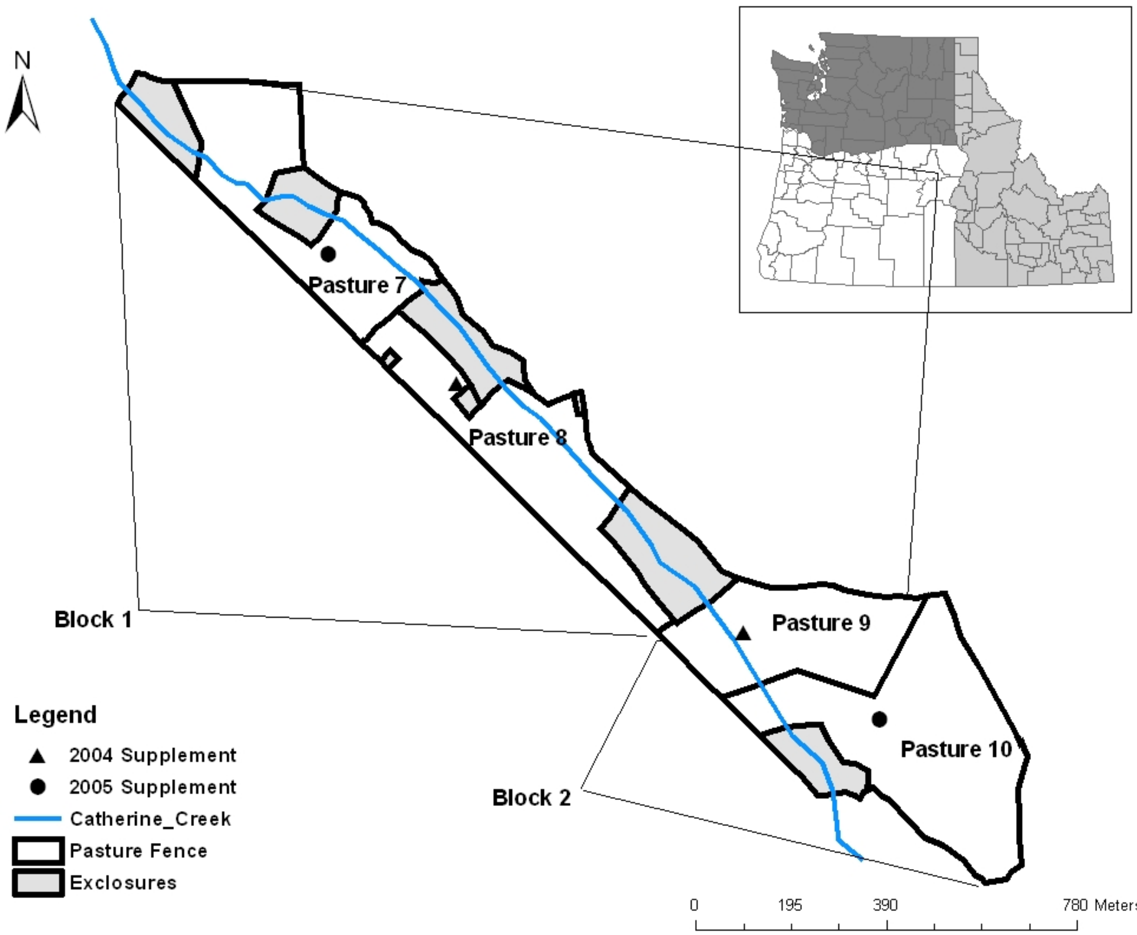

Figure 3-2. Catherine Creek Study Site - Portion of Catherine Creek on Oregon State University's Hall Ranch utilized for the research project. Four pastures (averaging 11 ha) and a 2,329 m stretch of Catherine Creek were utilized to evaluate the effect of protein supplementation on livestock performance, diet quality, and composition. All pastures have streams and riparian meadow plant communities. Grey areas represent exclosures inside experimental pastures used for other long-term research. Treatments in 2004 (Year 1) were randomly assigned as follows: Pastures 8 and 9 = protein supplement, Pastures 7 and 10 = no supplement. Treatment assignments for 2005 (Year 2) were reversed from Year 1.

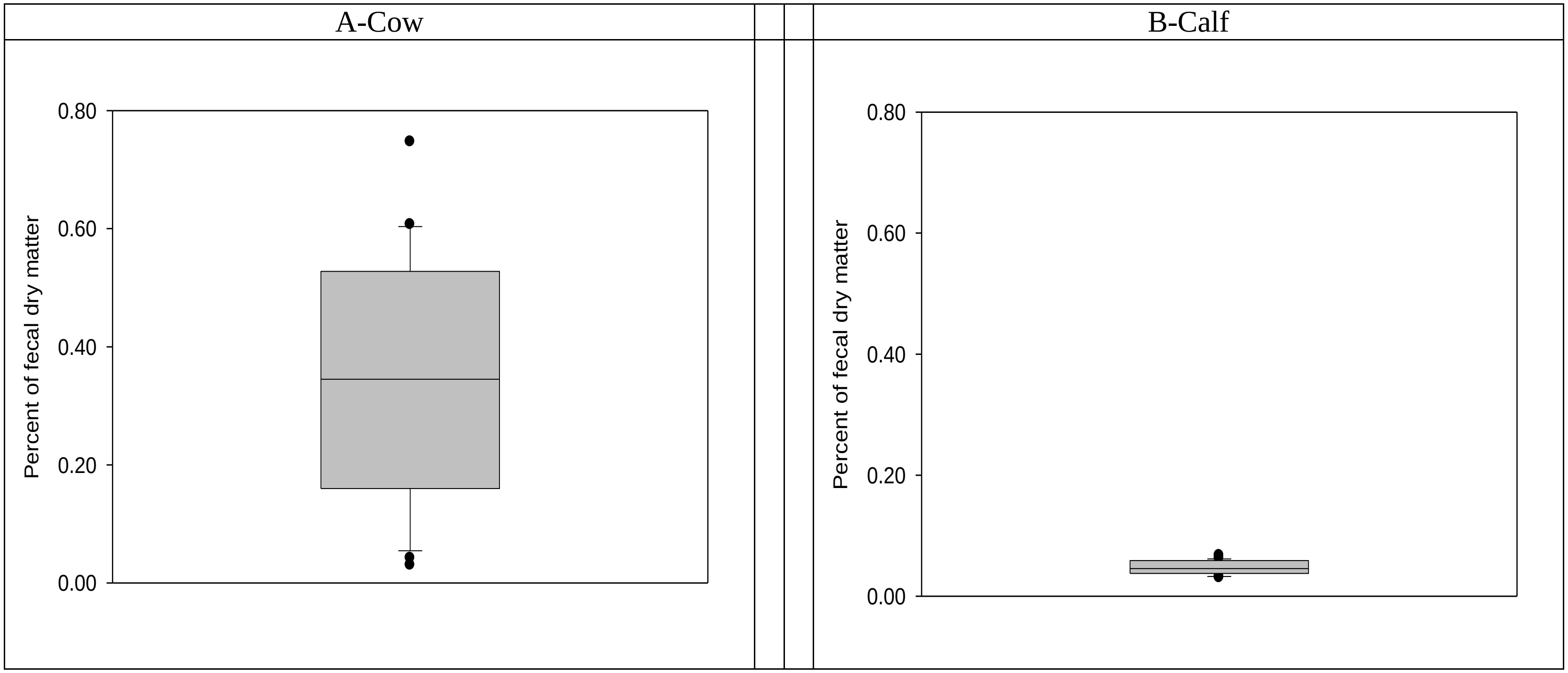

Figure 3-3. Average daily concentrations of TiO_2 (percent of fecal dry matter) in a) cow and b) calf fecal samples collected in July and August of 2004 and 2005 at pastures along Catherine and Milk Creeks in northeastern Oregon. Titanium dioxide was used as a marker in protein supplements provided for the animals, and helps illustrate the variation in supplement consumption.

Table 3-1. Nutritive quality of the common plant species occurring in cattle pastures along Catherine and Milk Creeks, northeastern Oregon. Samples were collected in July and August of 2004 and 2005 and assessed for Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Crude Protein (CP) and *In Vitro* Dry Matter Digestibility (IVDMD).Diet composition expressed as percent of total diet as ascertained from fecal samples of cows and calves in pastures along Catherine and Milk Creeks in northeastern Oregon. Samples were collected in July and August of 2004 and 2005.

Forage species	**Neutral Detergent Fiber (%)**	**Acid Detergent Fiber (%)**	**Crude Protein (%)**	***In vitro* Dry Matter Digestibility (%)**
Catherine Creek				
Grass				
creeping bentgrass (*Agrostis alba*)	62.28	36.49	5.67	62.79
Kentucky bluegrass (*Poa pratensis*)	66.96	36.44	6.89	63.37
Grasslike plants				
elk sedge (*Carex geyeri*)	65.68	36.18	6.39	62.10
Forbs				
western yarrow (*Achillea millefolium*)	58.30	44.21	9.09	52.27
red clover (*Trifolium pratense*)	47.17	33.95	13.77	73.77
Shrubs				
MacKenzie's willow *(Salix rigida)*	28.56	19.81	17.68	73.45
common snowberry (*Symphoricarpos albus*)	34.45	22.28	9.55	80.57
Milk Creek				
Grass				
creeping bentgrass (*Agrostis alba*)	64.55	36.03	5.40	60.02
Kentucky bluegrass (*Poa pratensis*)	69.63	39.12	5.97	60.60

Grasslike plants				
elk sedge (*Carex geyeri*)	63.69	29.75	6.09	62.90
Forbs				
western yarrow (*Achillea millefolium*)	54.65	40.49	8.29	60.51
red clover (*Trifolium pratense*)	43.37	28.80	15.97	62.08
Shrubs				
MacKenzie's willow (*Salix rigida*)	35.33	19.18	13.16	77.45
common snowberry (*Symphoricarpos albus*)	28.37	17.31	12.73	63.51

Table 3-2. Diet composition expressed as percent of total diet as ascertained from fecal samples of cows and calves in pastures along Catherine and Milk Creeks in northeastern Oregon. Samples were collected in July and August of 2004 and 2005.

Study Pasture and Plant Class	**Animal Type**	**Treatment Paddocks**	**Control Paddocks**	**P -Value**
Catherine Creek		**---------------- % in Diet ± SE ----------------**		
Grass	Cow	44.13 ± 3.15	52.88 ± 3.15	0.14
	Calf	40.15 ± 5.65	43.95 ± 5.65	0.67
Grasslike	Cow	39.38 ± 2.48	30.38 ± 2.48	0.08
	Calf	40.43 ± 4.66	33.15 ± 4.66	0.35
Forb	Cow	7.53 ±1.29	7.08 ± 1.29	0.82
	Calf	10.23 ± 2.98	9.60 ± 2.98	0.89
Shrub	Cow	5.10 ± 1.18	7.73 ± 1.18	0.21
	Calf	7.13 ± 0.94	9.15 ± 0.94	0.23
Other	Cow	3.88 ± 0.97	1.95 ± 0.97	0.25
	Calf	2.08 ± 1.66	4.18 ± 1.66	0.44
Milk Creek				
Grass	Cow	69.15 ± 1.67	67.15 ± 1.67	0.44
	Calf	63.03 ± 2.04	62.72 ± 2.04	0.92
Grasslike	Cow	18.55 ± 2.00	23.14 ± 2.00	0.17
	Calf	23.48 ± 1.56	21.40 ± 1.56	0.39
Forb	Cow	8.47 ± 0.92	6.70 ± 0.92	0.23
	Calf	10.90 ± 1.13	12.52 ± 1.13	0.36
Shrub	Cow	1.95 ± 0.44	0.45 ± 0.44	0.06
	Calf	1.88 ± 0.43	2.20 ± 0.43	0.62
Other	Cow	1.88 ±1.21	2.57 ± 1.21	0.71
	Calf	0.70 ± 0.35	1.17 ± 0.35	0.39

Table 3-3. Performance measures (mean ± SE) of cows and calves in pastures along Catherine and Milk Creeks in northeastern Oregon in July and August of 2004 and 2005.

Performance measure	Supplement	No Supplement	P-value
Catherine Creek			
Cow initial weight (kg)	523.61 ± 26.72	542.5 ± 26.25	0.64
Cow weight change (kg)	19.40 ± 5.58	6.49 ± 5.49	0.20
Calf initial weight (kg)	201.8 ± 7.44	194.7 ± 7.34	0.54
Calf average daily gain (kg)	1.08 ± 0.02	1.02 ± 0.02	0.18
Cow initial body condition[a]	4.27 ± 0.37	4.46 ± 0.36	0.73
Cow body condition change[a]	0.05 ± 0.19	-0.19 ± 0.19	0.44
Milk Creek			
Cow initial weight (kg)	533.43 ± 14.32	526.17 ± 14.32	0.73
Cow weight change (kg)	35.41 ± 2.38	23.24 ± 2.38	0.02
Calf initial weight (kg)	193.35 ± 3.31	191.93 ± 3.31	0.78
Calf average daily gain (kg)	1.29 ± 0.04	1.24 ± 0.04	0.31
Cow initial body condition[a]	4.55 ± 0.21	4.38 ± 0.21	0.57
Cow body condition change[a]	0.19 ± 0.05	0.08 ± 0.05	0.21

[a] This is a unitless measure, and is a score based on a scale of 1-10.

APPENDICES

Appendix 1 - Catherine Creek Forage Quality

Forage type	DM (%)	NDF (%)	ADF (%)	CP (%)	IVDMD (%)
creeping bentgrass (*Agrostis alba*)	96.42	62.28	36.49	5.67	62.79
mountain brome (*Bromus carinatus*)	95.96	73.57	44.80	5.28	56.78
quackgrass (*Elymus repens*)	96.68	65.17	35.93	8.04	65.18
Western fescue (*Festuca occidentalis*)	96.91	68.88	39.13	6.47	53.30
timothy (*Phleum pratense*	96.38	63.68	37.18	4.88	61.22
Kentucky bluegrass (*Poa pratensis*)	96.60	66.96	36.44	6.89	63.37
creeping bentgrass (*Agrostis alba*)	96.42	62.28	36.49	5.67	62.79
Grasslike plants					
elk sedge (*Carex geyeri*)	96.74	65.68	36.18	6.39	62.10
Forbs					
common yarrow (*Achillea millefolium*)	105.57	58.30	44.21	9.09	52.27
heartleaf arnica (*Arnica cordifolia*)	95.96	39.02	23.49	9.64	85.87
woodland strawberry (*Fragaria vesca*)	95.60	42.43	19.14	11.12	86.29
red clover (*Trifolium pratense*)	96.52	47.17	33.95	13.77	73.77
Shrubs					
MacKenzie's willow (*Salix rigida*)	95.83	28.56	19.81	17.68	73.45
cottonwood (*Populus spp.*)	96.65	34.41	22.30	12.29	79.51
common snowberry (*Symphoricarpos albus*)	95.99	34.45	22.28	9.55	80.57

Appendix 2 – Milk Creek Forage Quality

Forage type	**DM (%)**	**NDF (%)**	**ADF (%)**	**CP (%)**	**IVDMD (%)**
Grass					
western needlegrass (*Achnatherum occidentale*)	96.56	73.31	42.20	4.91	49.98
creeping bentgrass (*Agrostis alba*)	96.63	64.55	36.03	5.40	60.02
meadow foxtail (*Alopecurus pratensis*)	96.74	68.24	39.53	4.23	54.91
Pinegrass (*Calamagrostis rubescens*)	96.47	62.74	34.52	7.95	66.22
orchardgrass (*Dactylis glomerata*)	96.68	74.94	44.76	6.21	43.04
tufted hairgrass (*Deschampsia caespitosa*)	96.51	68.01	35.65	7.26	53.87
blue wildrye (*Elymus glaucus*)	96.90	68.12	41.37	5.81	53.05
western wheatgrass (*Pascopyrum smithii*)	96.63	66.66	38.77	5.88	52.46
Kentucky bluegrass (*Poa pratensis*)	96.84	69.63	39.12	5.97	60.60
Grasslike plants					
elk sedge (*Carex geyeri*)	96.82	63.69	29.75	6.09	62.90
Baltic rush (*Juncus balticus*)	96.22	70.37	33.16	7.28	35.50
Forbs					
western yarrow (*Achillea millefolium*)	95.89	54.65	40.49	8.29	60.51
yellow salsify (*Tragopogon dubius*)	96.43	51.66	37.39	5.77	48.73
red clover (*Trifolium pratense*)	96.28	43.37	28.80	15.97	62.08
Shrubs					
thinleaf alder (*Alnus incana*)	95.99	32.98	21.25	18.03	76.54
MacKenzie’s willow (*Salix rigida*)	95.33	35.33	19.18	13.16	77.45
common snowberry (*Symphoricarpos albus*)	95.87	28.37	17.31	12.73	63.51

FUTURE RESEARCH

- Supplement
  - Form
    - Cotton seed meal pellets (something that a pack horse could pack in)
    - Different palatability levels
    - Different protein levels
    - Provide energy supplement
  - Delivery method
    - Hand-fed
    - Cue (whistle or bell)
  - Frequency
    - Variable reward
    - Weekly delivery
  - Amount
    - Provide only enough for the dominant cows to consume
- Site
  - Combine with and without other off stream attractants
    - Water
    - Shade
    - Fly control
    - Upland pasture improvement (burning/fertilization)
  - Compare different sizes of pastures
  - Different habitat types (sagebrush grasslands, prairie, higher and lower elevations)
- Livestock
  - Three year old cows versus older cows
  - Yearlings
  - Track reproductive performance
- Economic Analysis
  - Assess cost to producer for supplement vs. loss of access to wider forage base
  - Track reproductive performance and winter feed costs after summer supplement treatment and economic impact
  - Cost of riparian damage/ loss of ecosystem services

LITERATURE CITED

Ansotegui, R. P., K. M. Havastad, J. D. Wallace, and M. L. Gaylean. 1988. Chemical composition of range forage consumed by cows and suckling calves. Journal of Animal Science 66: 191.

Association of Analytical Chemists. 1990. Official methods of analysis of the Association of Official Analytical Chemists 15th ed. Association of Analytical Chemists, Arlington, Virginia.

Bailey, C. B., and J. E. Lawson. 1981. Estimated water and forage intakes in nursing range calves. Canadian Journal of Animal Science 61: 415-421.

Bailey, D. W. 2004. Management strategies for optimal grazing distribution and use of arid rangelands. Journal of Animal Science 82: E147-E153.

Bailey, D. W., D. D. Kress, D. C. Anderson, D. L. Boss, and E. T. Miller. 2001a. Relationship between terrain use and performance of beef cows grazing foothill rangeland. Journal of Animal Science 79: 1883-1891.

Bailey, D. W., J. W. Walker, and L. R. Rittenhouse. 1990. Sequential analysis of cattle location: Day to day movement patterns. Applied Animal Behaviour Science 25: 137-148.

Bailey, D. W., and G. R. Welling. 1999. Modification of cattle grazing distribution with dehydrated molasses supplement. Journal of Range Management 52: 575-582.

Bailey, D. W., and G. R. Welling. 2007. Evaluation of low-moisture blocks and conventional dry mixes for supplementing minerals and modifying cattle grazing patterns Rangeland Ecology and Management: 54-64.

Bailey, D. W., G. R. Welling, and E. T. Miller. 2001b. Cattle use of foothills rangeland near dehydrated molasses supplement. Journal of Range Management 54: 338-347.

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Impacts of grazing intensity and grazing systems on vegetation composition and production. Journal of Soil and Water Conservation 54: 419-431.

Bennett, K. L., and J. Troyer. 2004. University of Idaho stubble height study report. 986, University of Idaho Forest, Wildlife and Range Experiment Station, Moscow, Idaho.

Bergman, C. M., J. M. Fryxell, C. C. Gates, and D. Fortin. 2001. Ungulate foraging strategies: Energy maximizing or time minimizing? Journal of Animal Ecology 70: 289-300.

Beschta, R. L. et al. 1995. A Catherine Creek study - perspectives, 1995-1998. Special Report 994, Oregon State University, Eastern Oregon Agricultural Experiment Station, Union, Oregon.

Bowman, J. G. P., and B. F. Sowell. 1996. Delivery method and supplement consumption by grazing ruminants: A review. Journal of Animal Science 75: 543-550.

Braatne, J. H., S. B. Rood, and P. E. Heilman. 1996. Life history, ecology and conservation of riparian cottonwoods in North America. In: R. F. Stettler, H. D. Bradshaw, P. E. Heilman and T. M. Hinckley (eds.) Biology of Populus: Implications for management and conservation. p 57-85. National Research Council of Canada, Ottawa, Ontario, Canada.

Bryant, L. D. 1982. Response of livestock to riparian zone exclusion. Journal of Range Management 35: 780-784.

Butler, P. J. 2000. Cattle distribution under intensive herded management. Rangelands 22: 21-23.

Clary, W. P., and W. C. Leninger. 2000. Stubble height as a tool for management of riparian areas. Journal of Range Management 53: 562-573.

Darambazar, E., T. DelCurto, C. Ackerman, G. D. Pulsipher, and D. Damiran. 2003. Changes in forage quantity and quality with continued cattle grazing in a mountain riparian pasture. Proceedings of the Western Section of American Society of Animal Science 54: 324-328.

Davitt, B. B. 1979. Elk summer diet composition and quality on the Colockum Multiple Use Research Unit, Central Washington. Master of Science Thesis, Washington State University, Pullman, Washington.

DelCurto, T., D. Bonhnert, and C. Ackerman. 2000. Strategic supplementation of beef cattle consuming low-quality roughages in the western United States. Station Bulletin 683, Oregon State University, Eastern Oregon Agricultural Experiment Station, Union, Oregon.

DelCurto, T., M. L. Porath, C. T. Parsons, and J. A. Morrison. 2005. Management strategies for sustainable beef cattle grazing on forested rangelands in the Pacific Northwest. Journal of Range Management 58: 119-127.

Dhuyvetter, D. V. et al. 1993. Reproductive Efficiency of Range Beef Cows Fed Different Quantities of Ruminally Undegradable Protein Before Breeding. Journal of Animal Science: 2586-2593.

Elmore, W., and B. L. Kovalchik. 1991. Effects of cattle grazing systems on willow-dominated plant associations in central Oregon. In: W. P. Clary, E. D. McArthur, D. Bedunah and C. L. Wambolt (eds.) Proceedings - symposium on ecology and management of riparian shrub communities, Sun Valley, Idaho. p 111-119. USDA Forest Service, Intermountain Research Station, General Technical Report INT-289, Ogden, Utah.

Faulkner, D. B. et al. 1994. Performance and nutrient metabolism by nursing calves supplemented with limited or unlimited corn or soyhulls. Journal of Animal Science 72: 470-477.

Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology 16: 629-644.

Flinders, J. T., and R. M. Hansen. 1972. Diets and habits of jackrabbits in northeastern Colorado. Colorado State University Press, Fort Collins, Colorado.

Ganskopp, D. 2001. Manipulating cattle distribution with salt and water in large arid-land pastures: A GPS/GIS assessment. Applied Animal Behaviour Science 73: 251-262.

Gentner, B. J., and J. A. Tanaka. 2002. Classifying federal public lands grazing permittees. Journal of Range Management 55: 2-11.

Gillen, R. L., W. C. Krueger, and R. F. Miller. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. Journal of Range Management 37: 549-553.

Green, D. M., and J. B. Kauffman. 1995. Succession and livestock grazing in a northeastern Oregon riparian ecosystem. Journal of Range Management 48: 307-313.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41: 540-551.

Holechek, J. L., and B. D. Goss. 1982. Evaluation of different diet calculation procedures for microhistological analysis. Journal of Range Management 35: 721-723.

Holechek, J. L., and R. Valdez. 1985. Magnification and shrub stemmy material influences on fecal analysis accuracy. Journal of Range Management 38: 350-352.

Hollingsworth, K. J. 1994. Escape protein, rumen degradable protein, or energy as the first limiting nutrient of nursing calves grazing native sandhills range. Ph.D. Dissertation, University of Nebraska, Lincoln, Nebraska.

Howery, L. D., F. D. Provenza, R. E. Banner, and C. B. Scott. 1996. Differences in home range and habitat use among individuals in a cattle herd. Applied Animal Behaviour Science 49: 305-320.

Howery, L. D., F. D. Provenza, R. E. Banner, and C. B. Scott. 1998. Social and environmental factors influence cattle distribution on rangeland. Applied Animal Behaviour Science 55: 231-244.

Huber, S. A. et al. 1995. Cattle grazing a riparian mountain meadow: Effects of low and moderate stocking destiny on nutrition, behavior, diet selection, and plant growth response. Journal of Animal Science 73: 3752-3765.

Huston, J. E., H. Lippke, T. D. A. Forbes, J. W. Holloway, and R. V. Machen. 1999. Effects of supplemental feeding interval on adult cows in western Texas. Journal of Animal Science 77: 3057-3067.

Kauffman, J. B., R. L. Beschta, N. Otting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22: 12-24.

Kauffman, J. B., and W. C. Kreuger. 1984. Livestock impacts on riparian ecosystems and streamside management implications: A review. Journal of Range Management 37: 430-438.

Kauffman, J. B., W. C. Kreuger, and M. Vavra. 1983a. Impacts of cattle on streambanks in northeastern Oregon. Journal of Range Management 36: 683-685.

Kauffman, J. B., W. C. Krueger, and M. Vavra. 1983b. Effects of late season cattle grazing on riparian plant communities. Journal of Range Management 36: 685-691.

Kauffman, J. B., M. P., P. Bayley, H. W. Li, and R. Beschta. 2002. Research / evaluate restoration of NE Oregon streams: Effects of Livestock Exclosures (Corridor Fencing) on Riparian Vegetation, Stream Geomorphic Features, and Fish Populations. DOE/BP-00006210-1, Bonneville Power Administration, Portland, Oregon.

Kay, C. E., and S. Chaddle. 1991. Reduction of willow seed production by ungulate browsing in Yellowstone National Park. In: W. P. Clary, E. D. McArthur, D. Bedunah and C. L. Wambolt (eds.) Proceedings - Symposium on ecology and management of riparian shrub communities, Sun Valley, Idaho. p 92-99. USDA Forest Service, Intermountain Research Station, General Technical Report INT-289, Ogden, Utah.

Kincheloe, J. J. 2004. Variation in supplement intake by grazing beef cows. Master of Science Thesis, Montana State University, Bozeman, Montana.

Korfhage, R. C. 1974. Summer food habits of elk in the Blue Mountains of northeastern Oregon based on fecal analysis. Master of Science Thesis, Washington State University, Pullman, Washington.

Kunkle, W. E., J. T. Johns, M. H. Poore, and D. B. Herd. 1999. Designing supplementation programs for beef cattle fed forage-based diets. Journal of Animal Science: 12.

Laliberte, A. S., D. E. Johnson, N. R. Harris, and G. M. Casady. 2001. Stream change analysis using remote sensing and Geographic Information Systems (GIS). Journal of Range Management 54: A22-A50.

Lamb, J. B., D. C. Adams, T. J. Kloppenstein, W. W. Stroup, and G. P. Lardy. 1997. Range or meadow regrowth and weaning effects on 2-year old cows. Journal of Range Management 50: 16-19.

Launchbaugh, K. L., and L. D. Howery. 2005. Understanding landscape use patterns of livestock as a consequence of foraging behavior. Rangeland Ecology and Management 58: 99-108.

Loy, T. W., G. P. Lardy, M. L. Bauer, W. D. Slanger, and J. S. Caton. 2002. Effects of supplementation on intake and growth of nursing calves grazing native range in southeastern North Dakota. Journal of Animal Science 80: 2717-2725.

Martin, S. C., and D. E. Ward. 1973. Salt and meal-salt help distribute cattle use on semidesert range. Journal of Range Management 26: 94-97.

McDougal, N. K., W. E. Frost, and D. E. Jones. 1989. Use of supplemental feeding locations to manage cattle use on riparian areas of hardwood rangelands. In: D. L. Abell (ed.) California riparian systems conference: Protection, management, and restoration in the 1990's. General Technical Report PSW-110. p 124-126. USDA Forest Service, Pacific Southwest Research Station, Davis, California.

Meyers, W. D., P. A. Ludden, V. Nayigihugu, and B. W. Hess. 2004. A procedure for the preparation and quantitative analysis of samples for titanium dioxide. Journal of Animal Science 82: 179-183.

Momont, P. A., and R. J. Pruitt. 1999. Condition scoring of beef cattle. In: J. R. Adams and M. W. Stellmon (eds.) Cow-calf management guide. College of Agriculture, University of Idaho, Moscow, Idaho.

Morrison, J. A., T. Delcurto, C. T. Parsons, E. S. Vanzant, and G. D. Pulsipher. 2002. The influence of cow age on grazing distribution and utilization of mountain riparian areas and adjacent uplands. In: Proceedings of the Western Section of American Society of Animal Science. p 118.

Mosely, J. C., E. L. Smith, and P. R. Ogden. 1990. Seven popular myths about livestock grazing on public lands. Idaho Forestry Wildlife and Range Experiment Station Bulletin 513, Moscow, Idaho.

Naiman, R. J., H. DeCamps, and M. Pollack. 1993. The role of riparian corridors in maintaining regional biodiversity. Ecological Applications 3: 209-212.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press, Washington, D.C.

National Research Council. 2002. Riparian areas: Functions and strategies for management. National Academy Press, Washington D.C.

Parsons, C. T., P. A. Momont, T. DelCurto, M. McInnis, and M. L. Porath. 2003. Cattle distribution patterns and vegetation use in mountain riparian areas. Journal of Range Management 56: 334-341.

Pechanec, J. F., and F. D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. Journal of American Society of Agronomy 29: 894-904.

Peinetti, H. R., R. S. C. Menezes, and M. B. Coughenour. 2001. Changes induced by elk browsing in the above-ground biomass production and distribution of willow (Salix monticola Bebb): Their relationships with plant water, carbon, and nitrogen dynamics. Oecologia 127: 334-342.

Pogacnik, T. M., and C. B. Marlow. 1986. Cattle feeding and resting patterns in a foothills riparian zone. Journal of Range Management 39: 212-217.

Porath, M. L. et al. 2001. Offstream water and trace mineral salt as management strategies for improved cattle distribution. Journal of Animal Science 80: 346-356.

Powell, G. W., K. J. Cameron, and R. F. Newman. 2000. Analysis of livestock use of riparian areas: Literature review and research needs assessment for British Columbia. Ministry of Forests Research Program, British Columbia, Canada.

Randel, R. D. 1990. Nutrition and postpartum rebreeding in cattle. Journal of Animal Science 68: 853-862.

Rhodes, B. J., and C. B. Marlow. 1997. Intensive range riding for improving livestock distribution. In: Proceedings - 50th Annual Meeting for the Society of Range Management, Rapid City, South Dakota. p 38-39.

Sarr, D. A. 2002. Riparian livestock exclosure research in western United States: A critique and some recommendations. Environmental Management 30: 516-526.

SAS. 1996. SAS User's Guide: Statistics. SAS Institute Incorporated, Cary, North Carolina.

Sawyer, J. E., and C. P. Mathis. 2000. Supplement delivery systems. Cooperative Extension Service Circular 571, New Mexico State University, College of Agiculture and Home Economics, Las Cruces, New Mexico.

Skovlin, J. M. 1957. Range riding: The key to range management. Journal of Range Management 10: 269-271.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992a. Declining forage availability effects on utilization and community selection by cattle. Journal of Range Management 45: 391-395.

Smith, M. A., J. D. Rodgers, J. L. Dodd, and Q. D. Skinner. 1992b. Habitat selection by cattle along an ephemeral channel. Journal of Range Management 45: 385-390.

Sparks, D. R., and J. C. Malechek. 1968. Estimating percentage dry weight in diets using a microscopic technique. Journal of Range Management 21: 264-265.

Stalker, L. A., D. C. Adams, T. J. Klopfenstein, D. A. Feuz, and R. N. Funston. 2006. Effects of pre- and postpartum nutrition on reproduction in spring calving cows and calf feed-lot performance. Journal of Animal Science: 2582-2589.

Steele, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics: A biometrical approach. 2nd ed. McGraw Hill, New York, New York.

Stricker, J. A. et al. 1979. Cow-calf production on tall fescue-ladino clover pastures with and without nitrogen fertilizer or creep feeding: Spring calves. Journal of Animal Science 48: 13-25.

Suverly, N. A. 1999. Management of stockpiled forage and optimal use of supplements by beef cattle while consuming low quality forages, Oregon State University, Corvallis, Oregon.

Taylor, G. H., D. Schulte, T. Parzybok, A. Bartlett, and C. Scalley. 1993. Climatological data for Oregon agricultural regions. Special Report 912, Oregon State University, Agri-cultural Experiment Station, Corvallis, Oregon.

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

Titgemeyer, E. C., C. K. Armendariz, R. H. Bindel, and R. H. Greenwood. 2001. Evaluation of titanium dioxide as a digestibility marker in cattle. Journal of Animal Science 79: 1059-1063.

Trask, M. 2001. Milk Creek riparian enhancement project. Biological Technical Report, Ore-gon Department of Transportation, Salem, Oregon.

Vavra, M., and J. L. Holechek. 1980. Factors influencing microhistological analysis of herbi-vore diets. Journal of Range Management 33: 371-374.

Vavra, M., and R. L. Phillips. 1979. Diet quality and cattle performance on forested range-land in Northeast Oregon. Proceedings of the Western Section of American Society of Animal Science 30: 170-173.

Winward, A. H. 2000. Monitoring the vegetation resources in riparian areas. General Tech-nical Report RMRS-GTR-47, USDA Forest Service Rock Mountain Research Sta-tion, Fort Collins, Colorado.