AN ABSTRACT OF THE THESIS OF

Micah Wells for the degree of Master of Science in Rangeland Resources presented on August 25, 2003.

Title: Influence of Cow Age/Experience and Landscape Thermal Regimes on Distribution and Grazing Patterns of Cattle in Northeastern Oregon Mixed Conifer Forested Rangelands

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Abstract approved: ______________________________
Martin Vavra

Two studies were conducted to determine the factors influencing distribution of cattle on northeastern Oregon mixed-conifer forested rangelands. The objective of the first study was the quantification of differences in distribution of cattle of different ages. Beginning in 1991, and continuing through 2001, radio telemetry collars were placed on a minimum of 30 cattle per year, prior to turnout. Cattle graze the forest from approximately 15 Jun until 15 Oct each year, and were grouped into four age classes: two and three year old cattle (group 1), four and five year old cattle (group 2), six and seven year old cattle (group 3), and cattle eight years of age and older (group 4). The objective of the second study was to determine differences in landscape thermal regimes between riparian and upland areas. Ambient and "black body" thermal probes were placed in a grid pattern in riparian and upland areas at a height of one meter (mid height of a cow), to encompass the entire pasture. For study 1, all groups of cattle preferred areas with shallow slopes ($P<0.05$), westerly

aspects ($P<0.05$). All age classes of cattle also preferred areas farther from water than the mean distance to water in the pasture ($P<0.05$) as well as areas with higher quantities of forage (kg/ha) than the mean value of forage production for the pasture ($P<0.05$). Cattle in age classes two, three and four selected areas with lower percent canopy closure of trees greater than 12 cm diameter, breast height (dbh), than the mean value for the pasture ($P<0.05$) Cattle in age class one selected for areas of lower elevation and slightly steeper slopes than cattle in age class four ($P<0.05$). Cattle in age class two were not affected by slope or elevation in their distribution ($P<0.05$). Cattle in age class three were not influenced by elevation in their distribution, but selected areas of the pasture with shallower slopes ($P<0.05$). For the second study, the trial was conducted from 5 Aug to 25 Sep in 2001, and from 15 Jul to 1 Sep in 2002. Year was found to be significant ($P<0.0001$), therefore results from each year were analyzed separately. Each six week grazing period was divided into three-week intervals, and deemed early and late season for each year. Season was found to be highly significant ($P< 0.0001$), and therefore analyzed separately within each year. Least significant means were utilized to determine differences in temperatures. Differences were considered significant at the $P<.05$ level for all analysis. Thermal probes were divided into two types within two areas; ambient and blackball, within riparian and upland areas. Analysis conducted examined the differences between riparian and upland ambient and blackball thermal probes. Area and type of probe were both highly significant ($P<0.0001$) for all classifications, however, there was not an area by type interaction.

Influence of Cow Age/Experience and Landscape Thermal Regimes on Distribution and Grazing Patterns of Cattle in Northeastern Oregon Mixed Conifer Forested Rangelands

by
Micah Wells

A THESIS

Submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented August 25, 2003
Commencement June 2004

Master of Science thesis of Micah Wells presented on August 25, 2003

APPROVED:

Redacted for Privacy

Major Professor, representing Rangeland Resources

Redacted for Privacy

Head of Department of Rangeland Resources

Redacted for Privacy

Dean of the Graduate School

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ACKNOWLEDGMENTS

There is not enough time or space to thank everyone who has helped me along the way. For those of you whom I forget, I am sure that my thanks are best given in person

Enough thanks can-not be given to my parents who have supported me through all of my college endeavors. Their constant support and love have inspired me to do what I never thought possible.

I would also like to thank Marty Vavra for having the foresight to see in me what I did not know existed. He took chance on me, and for that I am forever grateful. He has become more than just my professor, he is a dear friend and an inspiration.

Tim and Tammy DelCurto, embraced me as one of their own children, why, I have no idea. I am sure there were times they wanted to make me sit in the corner and think about what I had done. Both have guided me through both good times and bad, and are two of the best people in the world.

I would also like to thank my good friend, and partner in crime Hoser, as well as his family (Mrs. Hoser, Hoserito, and McKenzed). There were times when I thought we would be reduced to riding peddle bikes, but somehow we made it through. Remember, the good news is, we're O.K.

I would like to thank all the people of the Experiment Station. Dr. Fite, you are truly one of a kind. Your ability to put up with all of our crazy ideas and last minute changes is mind blowing. Spoon, thanks for being there whenever. Janna Banana and Accountress, you helped me whenever I had one of my emergencies, and always had a smile for me. A very special thanks must be given to Trent who helped me the first summer get my project done. You were right Trent, we weren't building a piano, but sometimes it seemed like we were carrying one. Gawey, thanks for the after work bull sessions, and remember, NEVER put coke in single malt.

Finally, I would like to thank Karen, for proving to me that it is cool to be a nerd, and that some chicks do dig it.

CONTRIBUTION OF AUTHORS

Bruce Johnson and Pricilla Coe were instrumental in their instruction of the implementation of the statistical program utilized to determine resource selection function for cattle. In addition, they provided habitat and cattle radio-telemetry data from the Starkey Experimental Forest and Range. Kenric Walburger aided in the design and placement of the thermal probes, as well as the analysis of the thermal data. Ronney "C" Slater provided an invaluable service in helping to develop the GIS layers to create the thermal image maps of Bear Pasture, and also in the correction GPS locations of the thermal probes.

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Chapter 1

INTRODUCTION

Introduction

Distribution and the subsequent grazing patterns of cattle on public rangelands in the West are often the catalyst fueling public outcry regarding public land use. Concerns regarding the uses of public lands were prominent long before the environmental movements of the 1960's and 1970's. Concerns were rising to such a degree during the peak of the dust bowl, that they culminated with the inception and subsequent passage of the Taylor Grazing Act in 1934 (43 USC 315).

With the implementation of the Taylor Grazing Act, the Secretary of the Interior was charged with creating, at his discretion, grazing districts. The purpose of which was "…to regulate their occupancy and use, to preserve the land and its resources from destruction or unnecessary injury, to provide for the orderly use, improvement, and development of the range…" (43 USC 315a).

The Grazing Service, created in order to manage the grazing districts, was later combined with the General Land Office in 1946 to form the Bureau of Land Management (BLM) (43 USC 1). The BLM and United States Forest Service, manage a large portion of the public lands on which grazing occurs.

Despite the management practices of the Forest Service and BLM, further concerns regarding the management of public lands resulted the passage of additional regulatory acts. The Multiple Use Sustained Yield Act (MUSY) of 1960 (16 USC 528) stated, "It is the policy of the Congress that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes."

In addition, the Federal Land Policy Management Act (FLPMA) of 1976 stated "…the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use…" (43 USC 1701).

As previously stated, management of the distribution patterns of cattle are the driving force behind many of our current federal land management policies. Therefore, it is imperative that resource managers understand the factors that influence cattle distribution patterns. It is possible to divide the forces of distribution into two categories of influence: Environmental, which pertains to the physical environment in which livestock graze, and Physiological, which encompasess the biotic characteristics of the animal, particularly age for the purposes of this discussion. Additionally, by applying what is known regarding the influence of both environmental as well as physiological factors, there are management options that may be employed to alter distribution in a manner to meet resource management goals.

Influence of Environmental Factors on Distribution

Environmental factors play a significant role in shaping the distribution patterns of livestock. It has been demonstrated that the primary factors affecting distribution are: slope, aspect, available forage, and distance to water (Cook 1965, Mueggler 1965, Bryant 1982, Roath and Krueger 1982, Senft et al. 1985, Walburger et al. 2000, Porath et al. 2002). Therefore, it is these environmental factors that will be the focus of discussion within the confines of this portion of the discussion.

Slope

Resource managers have recognized the importance of slope in distribution, for an extensive period of time. Cook (1965) examined the factors affecting the utilization of mountain slopes by cattle. In an attempt to quantify which variables influenced the use of slope, Cook (1965) found that a single measure of slope was not adequate for evaluating the influence of slope on utilization, rather topography, brush, distance from water, and salting all influenced the use of slopes.

Using cow chips as a measure of animal distribution and relative use, Mueggler (1965) found that for any particular steepness of slope, cattle use was greatest at the bottom of the slope. These results were congruent with those of Bryant (1982), who found that as slope increased, the frequency of use by livestock classes decreased, and slopes of less than thirty five percent were preferred.

In a study by Gillen et al. (1984), slope was the only physical factor that consistently affected cattle distribution, and was again found to be inversely associated with cattle preference. In addition, cattle avoided slope gradients greater than twenty percent.

Results from Ganskopp and Vavra (1987) also demonstrated the preference of cattle to slopes between 0 and 9 percent. Three pastures (A, B, and C) ranging from 0 to greater than 50 percent slope were utilized during the 1979 and 1980 grazing seasons on the east bank of the Owyhee Reservoir, with pasture C being the must rugged. The percentage of cattle observed in the 0 to 9 percent slope regions of each pasture were greater than the available percentages. In this study, cattle avoided slopes greater than 20 percent in all three pastures. The upper limit of slope use in pastures A and B was in the 20 to 29 percent category. Pasture C (the most rugged) saw slope use of 30 to 39 percent by cattle.

Aspect

The influence of aspect on distribution is highly correlated with forage availability and quality. In a study assessing the influence of grazing systems and forage quality on distribution, Walburger et al. (2000) found that forage quality and distribution patterns were affected by aspect. As the grazing season progressed, crude protein (CP) and *In vitro* dry matter digestibility (IVDMD) of Idaho fescue (*Festuca idahoensis*) declined overall, but less so on north facing aspects. This in turn, affected distribution to a greater extent as the grazing season progressed, causing cattle to utilize north facing aspects. However, two additional studies found that aspect was not a determinant factor in distribution (Bryant 1982, Sheehy and Vavra 1996).

Available Forage

Roath and Krueger (1982), examined cattle grazing and behavior on forested range concluding that livestock dispersion was not uniform across vegetation types or landscape. Based on a proportional basis, (area utilized versus total available area) the vegetation types grazed usually represented a larger proportion of the area grazed than of the total area available, thus indicating preferential use of some vegetation types over others. In this example, the bluegrass bottom areas (riparian) of the study pasture, comprised twenty one percent of the total biomass produced, however, they provided eighty one percent of the forage consumed. In contrast, consumption of upland vegetation tended to be low.

A study assessing the factors influencing grazing patterns of cattle (Senft et al. 1985) determined that relative measures of forage quality and quantity were good predictors of community preference, and therefore distribution. Both studies are congruent with the findings of Bailey et al. (1996), Kie and Boroski (1996) and Walburger et al. (2000) who all noted that forage availability, quality and quantity were driving factors in determining cattle distribution.

Distance to Water

Distance to water is of extreme importance in the distribution patterns of cattle. In reviewing the available literature, a virtual plethora of studies can be found where distance to water is the ubiquitous force in distribution. Numerous studies have indicated that distribution of cattle is directly impacted by distance to water (Cook 1965, Mueggler 1965, Roath and Krueger 1982, Owens et al. 1991, Bailey et al. 1996, and Porath et al. 2002). Although many studies noticed the apparent influence of water on distribution, very few were designed to quantify the direct influence of water.

The objective of Porath et al. (2002) was the direct quantification of offstream water in conjunction with trace mineral salt and the subsequent influence of distribution. The study was a replicated design with randomly assigned treatments. The treatments included 1) access to both the stream and offstream water with trace mineral, 2) stream access and no access to offstream water or trace mineral, and 3) an ungrazed control treatment. Cattle with access to offstream water consumed forty five percent of their required daily water intake from the offstream water source; despite the fact the offstream water source was five degrees Celsius warmer than the water in the stream. It was surmised that both cattle distribution and cow/calf performance were influenced by the presence of the offstream water and trace mineral salt.

Influence of Physiological Factors on Distribution

The responses of cattle grazing to varying environmental conditions are in part determined by certain physiological characteristics of the cattle in question, such as breed type, body weight, lactation status, and gender. Within the confines of this discussion, the age of individual cattle will be the focus. There is a limited amount of literature available discussing the direct effects of age on distribution.

A study by Neville (1971) estimated the effect of age on the energy requirements of lactating Hereford cows. Neville wanted to determine whether the energy requirements of lactating Hereford cows varied by age. Cattle were grouped as young (two year olds), mature (six year olds) and aged (twelve year olds). Differing energy requirements between age classes of cattle could manifest themselves as distinct differences in distribution, in order to satisfy varying energy needs. However, Neville concluded there was no indication that age affected energy requirements, despite cows' weight, milk production and weight/height at hip ratio increased linearly up to six years of age.

These results differ from those found by Hunter and Siebert (1986), who showed that with increasing age and live weight of steers, intake per unit of body weight declined. A reduction in intake per unit of body weight could once again, display differences in distribution, due to differing energy requirements.

An experiment conducted by Ralphs and Cheney (1993) analyzed the effects of cattle age, Lithium Chloride (LiCl) dosage levels, and food type in the retention of food aversions. The formation and retention of aversions to specific types of feeds could be utilized to shape distribution patterns. Three levels of LiCl were given to yearling and mature (three to four year old) cattle to test food aversions to licorice flavored alfalfa pellets and beet pulp. Ralphs and Cheney (1993) found that a dose of 200 mg/kg of LiCl was sufficient for mature cows to retain a high level of aversion to beet pulp, while 300 mg/kg of LiCl was required for the yearling cattle to maintain an aversion to the beet pulp.

Cazcarra and Petit (1995) examined the influence of age and sward height on the intake of herbage and grazing behavior on Charolais cattle. Eight, mature cows, eight - seventeen to nineteen month old heifers and eight - seven to eight month old calves were utilized and randomly assigned to treatment groups. Swards were divided into four groups, short and tall, and time one and time two. Swards were harvested and the subsequent ages of regrowth were two and nine weeks for the first period and two and eight weeks for the second period. Each period lasted fifteen days, with cattle being randomly allocated to tall or short treatments, and then switched for the second fifteen-day grazing period.

Intake expressed on a kg per live weight basis, indicated that no significant interaction on herbage intake per kg live weigh was found. Calves and heifers displayed similar grazing times, with grazing times of cows being lower, and cows in the short sward treatments taking fewer bites per day than heifers. Cazcarra and Petit (1995) concluded that a decrease in the height of herbage and mass first increases the rate of biting, then the grazing time in all cattle, regardless of age. Growing cattle attempt to satisfy their higher requirements, on a body weight percentage, by increasing their grazing time and number of bites per day. Heifers maintained similar biting rates to cows, which allowed them to attain higher mean grass intake on a kg per live weight basis. Heifers also appeared to display a greater sensitivity in regard to forage quality.

Beaver and Olson (1997) examined the differences in distribution and subsequent use of winter range between young (three year old) cattle with no experience with mature (seven to eight year old) cattle on the same pasture over a two-year period. Locations of cattle were noted as either in protected, moderately protected, or unprotected in relation to wind direction and topography. The three-year-old cattle used the unprotected areas more frequently than the seven to eight year old cattle.

Beaver and Olson (1997) concluded that the differences in distribution could be accounted for by several factors: 1) Three year old cattle were not pregnant the first winter of the study, however the behavior of pregnant three year old cattle in winter two was more similar to three year old cattle of winter one than seven and eight year old cattle. 2) Age regardless of experience may be the driving factor in the differences in distribution. 3) Younger cattle travel more than older cattle, thus incurring greater demands on available energy. 4) The experience in the pasture that the seven and eight year old cattle had relative to the first time experience by the three-year-old cattle could explain the differences in distribution.

Bryant (1982) initiated a study in which one of the objectives was the evaluation of the differences in use patterns of yearlings and cows with calves. Bryant (1982) concluded the difference in patterns of use was a response interaction among the vegetation's phenological condition, grazing preference and climatic changes. Cows with calves grazed the most productive forage areas to a wider extent than did yearlings. In addition, cows with calves have a greater energetic demand than yearling cattle without calves. Therefore, by selecting for plant communities of higher productivity, the cows were able to fulfill their higher energy demands easier. Cows also tended to use areas with steeper slopes than did yearlings. Bryant concluded that the higher level of experience on the range of the cow-calf pairs could account for this difference in use.

A recent study by Morrison et al. (2003) quantified the effects of age of cattle on distribution patterns. The study was a balanced and replicated design, which tested the distribution patterns of mature cows against those of first calf heifers. During the morning period of grazing, sunup until noon, mature cows distributed farther from the stream and spent less time in the riparian areas than the first calf heifers. The mature cows averaged 253 m from the stream, (showing preference for the upland areas), while the first calf heifers averaged 136 m from the stream, during the early time period (sun up until noon). However, there were no differences in distribution between age groups from 1300 until dark. Morrison observed that both age classes of cattle preferred areas closer to the stream as both the day and grazing season progressed.

The Influence of Landscape and Temperature on Distribution and Grazing Behavior

Thermal regimes on a landscape are influenced by a multitude of factors, each contributing to the resulting temperature. Altitude, aspect, solar radiation, position of the sun, time of year, time of day, wind, humidity, and spectral distribution of sunlight vary on a microclimatic level (Aussenac, 2000). Each microclimate in turn displaces individual thermal characteristics. Lowland areas are sinks for cooler denser air, resulting in diurnal thermal inversions across landscapes (Thompson and Dickson, 1958). These inversions are responsible for cool air patches and sinks in the lowland areas. These factors influence the behavior and physiological response of the cattle.

Several recent studies reported the influence of ambient temperature on cattle distribution (Beaver and Olson, 1997, Parsons et al. 2002, Porath et al, 2002, Morrison et al. 2003). All studies suggested the diurnal thermal patterns were responsible for daily shifts in cattle distribution. Cattle were often found in the upland areas in the early morning hours. In most cases, distribution would be somewhat random during the mid-day period. Cattle tended to bed down in riparian areas in the mid to late afternoon, and return to upland areas for evening grazing bouts and to bed down for the evening.

In addition to general landscape properties, vegetative structure on the microclimatic level influences temperatures as well. Potter et al. (2001) studied the impact of forest structure, (clear cut, partially cut, and uncut) on near ground temperatures during contrasting thermal years. They noted that differences between average and minimum air temperatures and soil temperature were less than instrumental error (0.3°C). However, maximum air temperature differences between the clear-cut and uncut sites dropped from 5.7°C in the cool year to 4.7°C in the warm year. The difference from the partial cut to no cut dropped from 3.2 to 2.7°C.

They concluded that the relationship between temperature microclimate and forest structure is not a constant, but is dependent on the magnitude of the temperature. Daily maximum temperatures showed less contrast between partially and fully open sites and closed sites in years of exceptional warmth.

Potter et al. (2001) recommended that a greater understanding of the differences in diurnal cycles of temperatures due to forest structure, and how the differences influence vegetation.

Liechty et al. (1992) also examined the changes in microclimate after stand conversion (hardwood harvested and converted to red pine). Soil temperatures and maximum air temperatures 2m above ground were increased by 5-25% after conversion.

Morecroft et al. (1998) studied the air and soil microclimates of deciduous woodland compared to an open site. They found that woodland air temperatures were lower than grassland, and decreased from the canopy to the understory, in the middle of a hot sunny day. The maximum differences between woodland and grassland air temperature was approximately 3°C. Woodland soil temperatures were lower than the air temperature, and decreased with depth as well. Maximum air temperatures occurred in the hour leading to 1500 GMT, with maximum soil temperatures lagging behind by increasingly larger amounts with increasing depth.

Thermal properties of a landscape and the resulting thermal regimes have pronounced effects on livestock. Numerous studies have been conducted analyzing the effects of temperature on cattle. Cattle, which are homeotherms, strive to maintain a balance between the heat gained and heat released from their body, in order to maintain a core body temperature within the thermal neutral zone (TNZ). The TNZ for beef cattle is 15-25° C, with 20° C considered the optimal temperature and the baseline for correction calculations (NRC, 1981). Encompassed within the outer bounds of the thermal neutral zone are the upper and lower critical temperatures. Temperatures in excess of 25° C are considered to be in the upper critical temperature zone, while those temperatures of –21 ° C or lower fall within the lower critical temperature zone.

Ambient temperature strongly effects digestion and metabolism (NRC, 1981) in beef cows. Increases and/or decreases in ambient temperature outside of the thermal neutral zone, can have marked effects on intake. Ambient temperatures in excess of 35°C can reduce intake of cattle on full feed by as much as 35 percent. Intakes are often stimulated when temperatures fall below the thermal neutral zone, in order to maintain the energy requirements of the body.

Solar radiation is a potentially uncontrollable source of heat to animals. Organisms receive long-wave radiation emitted from the atmosphere, the substrate, and other surroundings such as vegetation (Walsberg, 1992).

Any substance, warmer than absolute zero (-273.2°C) radiates energy at a rate directly proportional to the fourth power of its absolute temperature. The rate of radiant energy emission for a perfect radiator, or "black body" may be found by the Stefan-Boltzmann law:

$$W=\sigma T^4$$

Where W is the rate of radiant energy emission (cal cm $^{-2}$ min $^{-1}$); σ is the Stefan-Boltzmann constant (8.132 x 10^{-11} cal cm^{-2} min^{-1} °K^{-4}); and T is the absolute temperature (°K) of the radiant surface (Brown, 1973).

Using the Stefan-Boltzmann law, cattle in a thermally neutral environment (20°C) experience an energy emission of .5993 cal cm^{-2} min $^{-1}$. However, cattle in a thermally stressed environment of –21°C emit .3279 cal cm^{-2} min $^{-1}$, while .7318 cal cm^{-2} min $^{-1}$ would be emitted in a 35°C environment.

The thermal load on the skin is dependent upon the amount of the coat's insulation through which the radiation penetrates prior to absorption. If the absorption occurs for the most part near the outer coat surface, then the major fraction of the heat is lost to the environment and does not reach the skin. However, if the radiation penetrates the coat, before being absorbed, coat insulation retards heat loss to the environment and increases the thermal load on the skin (Walsberg, 1992). Walsberg (1992) also noted the thermal effects of radiation penetration can be rather large. This penetration is estimated to increase the heat load on the skin by up to 300% in cattle.

Heat dissipation in cattle, as stated earlier, is of utmost importance, due to the requirement of maintaining the balance between heat produced by the metabolic process and heat transfer to the environment. Recently, Ehrlemark and Sallvik (1996) developed a model of heat and moisture dissipation from cattle based on thermal properties. There are four basic elements and principles used as the basis of their model: 1) The body temperature is assumed to be constant and the change in heat is therefore negligible 2) At a given ambient temperature, the range of possible nonevaporative heat dissipation is limited 3) The total heat production of the animal is assumed to be constant within the thermoneutral zone 4) Following the principle of "least thermoregulatory effort", it is assumed that nonevaporative regulation is used in favor of evaporative regulation in the lower range of the thermoneutral zone.

In the model developed by Ehrlemark and Sallvik (1996), the division of total heat production into nonevaporative and evaporative heat loss is governed by ambient temperature. The evaporative part is 20% at –10°C and increases to 100% at approximately 36°C, which is the next incremental temperature above the upper critical limit of 35°C (NRC, 1981).

Hahn (1999) studied the responses of cattle to thermal heat loads using tympanic temperature readings of cattle. Hahn concluded there are two stages of coping with the acute phase of hot conditions. The first being increased heat dissipation, which occurs primarily through evaporative heat loss, and second, by reduced feed intake to lower metabolic heat production. As the tympanic temperature declined, the level of feed intake increases, but not necessarily to the prior level at cooler temperatures. It was apparent to Hahn, that the entrainment of body temperatures by the diurnal cycle of ambient temperatures has a three to four hour lag time.

Mendel et al. (1971) studied the effects of heat exposure and performance on beef cattle. Cattle were housed inside thermally stable buildings and outside as well, feeding and behavior were observed for each treatment. The objective of the study was to determine the minimum amount of cooling required in order to maintain feed performance. Mendel observed that 12 hr of cooling during the day was more effective than a similar period of cooling at night. It was also noted that a six-hour period of cooling in the evening (1600-2200) maintained body weight gains equal to those obtained with 12 hours of cooling during the day.

Water consumption is dramatically effected by ambient temperature as well. Generally, water intake is dependent upon availability. Grazing cattle with water available free-choice, drink 2 to 5 times in a 24-hour period (NRC, 1981). As the ambient temperature increases, water intake increases as well. Although water is available to cattle from the forage, seasonality and differing forage types are responsible for a large amount of variability in available water. Therefore as the grazing season progresses, a greater proportion of water consumed must be consumed from stock tanks or streams.

Management Options to Alter Cattle Distribution

Skovlin (1965) surmised that uneven distribution of cattle on mountain rangelands of the West was responsible for the diminishment of yields on highly productive areas, while forage on less accessible areas was unused. He recommended several potential methods to improve the distribution of cattle: 1) fencing, 2) development new water sources, 3) salting of lightly grazed areas, 4) construction of trails to improve access to isolated areas, 5) herding or range riding, and 6) management of forage.

Numerous studies have reinforced the findings and recommendations of Skovlin (Cook 1965, Bryant 1982, Roath and Krueger 1982, and Porath et al. 2002), and in turn, have become common practice in most rangeland management situations. Recent focuses on means of altering distribution have displayed increased focus on influences controlled by the animal more than the surrounding environment.

A repellent effects study by Engle and Schimmel (1984) treated areas of a rangeland with a deer and elk repellent in order to alter the distribution of steers grazing the area. Although there was no significant difference found in distribution between the treated and untreated areas, Engle and Schimmel (1984) noted a post application short-term decline in the presence of steers in the treated areas. Engle and Schimmel concluded because the repellent was applied after steer grazing preferences were probably fixed; significant alterations of distribution were not realized. They hypothesized that an earlier application of the repellent may have increased its effectiveness.

Howery et al. (1996) examined the potential of culling cattle that showed a stronger preference for riparian areas than other cattle in the herd. They concluded that selective culling of cattle that were "riparian abusers" could in fact alter overall distribution patterns of cattle. The option of culling non-desirable cattle based on their tendencies to occupy riparian areas operates under the assumption that the void that is left in their absence will not be filled by another cow. However, the authors hypothesized that the high degree of home range fidelity displayed by both wild and domestic ungulates would prevent such an occurrence.

As demonstrated by review of the available literature, there is interest in the influence of age of cattle on distribution. However, the availability of replicated, balanced studies that quantify the effects of age is limited. In addition, studies, which do address the direct influence of age, tend to focus on two or perhaps three age classes of cattle.

Studies regarding the influence of temperature focused on controlled themal environments, or winter - feeding situations, with little research focusing on the influence of temperature in summer grazing situations.

The need for further investigation into the influence of age and thermal regimes on cattle distribution is apparent. In the following two chapters, our objectives were to determine the differences in distribution between cattle as young as two years old, to those in excess of fourteen years of age, as well as the influence of landscape thermal regimes on cattle distribution as a whole.

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Chapter 2

THE INFLUENCE OF COW AGE/EXPERIENCE ON DISTRIBUTION AND GRAZING PATTERNS OF CATTLE ON NORTHEASTERN OREGON MIXED CONIFER FORESTED RANGELANDS

Micah S. Wells, Martin Vavra, Timothy DelCurto

Authors are Graduate Research Assistant, Department of Rangeland Resources, Oregon State University, Corvallis, Oregon, 97331; Professor, Department of Rangeland Resources, Eastern Oregon Agricultural Research Center, Oregon State University, Burns, Oregon, 97720; Associate Professor, Department of Animal Sciences, Oregon State University, Eastern Oregon Agricultural Research Center, Oregon State University, Union, Oregon, 97883

Abstract

Optimal distribution of cattle in forested rangelands has long been a subject of concern specifically related to uniform and sustainable use of forage resources. Limited information exists regarding the influence of cow age/experience on distribution patterns and resource use. Therefore, the objective of this study was the quantification of differences in distribution of cattle of different ages. Differences in distribution habits of cattle of different ages were monitored on an allotment pasture of the USDA Starkey Experimental Forest and Range, a northeastern Oregon mixed-conifer forested rangeland, consisting of approximately 3,200 ha. Beginning in 1991, and continuing through 2001, radio telemetry collars were placed on a minimum of 30 cattle per year, prior to turnout onto the forested rangeland. Cattle graze the forest from approximately 15 Jun until 15 Oct each year. The allotment is grazed on a four pasture, deferred rotation system. Bear Pasture is typically the middle pasture in the rotation, and is grazed for a six-week grazing period. Although observations were recorded on a 24-hour basis, only those observations that were recorded during peak grazing hours were utilized in the analysis. Peak grazing hours were considered to be one hour prior to sunup, four hours after sunup, and again four hours prior to sundown, and one hour after sundown. Sunrise and sunset from Greenwich mean sunrise and sunset tables. A total of 43,039 individual observations of cattle were utilized in the analysis. Cattle were grouped into four age classes: two and three year old cattle (group 1), four and five year old cattle (group 2), six and seven year old cattle (group 3), and cattle eight years of age and older (group 4). All groups of cattle preferred areas with shallow slopes ($P<0.05$), westerly aspects ($P<0.05$). All age

classes of cattle also preferred areas farther from water than the mean distance to water in the pasture ($P<0.05$) as well as areas with higher quantities of forage (kg/ha) than the mean value of forage production for the pasture ($P<0.05$). Cattle in age classes two, three and four selected areas with lower percent canopy closure of trees greater than 12 cm dbh, than the mean value for the pasture ($P<0.05$) Cattle in age class one selected for areas of lower elevation and slightly steeper slopes than cattle in age class four ($P<0.05$). Cattle in age class two were not affected by slope or elevation in their distribution ($P<0.05$). Cattle in age class three were not influenced by elevation in their distribution, but selected areas of the pasture with shallower slopes($P<0.05$). In summary, cow age/experience directly influences distribution patterns and forage resource use.

Keywords: Age class, distribution, slope, aspect, forage production, distance to water

Introduction

Management of the distribution patterns of cattle is the driving force behind many of our current federal land management policies. Therefore, it is imperative that resource managers understand the influence of the factors involved in cattle distribution patterns. It is possible to divide the factors of distribution into two categories of influence: Environmental, which pertain to the physical environment in which livestock graze, and Physiological, which encompass the biotic characteristics of the animal.

The influence of environmental factors such as slope, aspect, forage production, and distance to water have been well documented in previous research (Cook, 1965, Mueggler, 1965, Ganskopp and Vavra, 1984, Senft et al., 1985,Roath and Krueger, 1987, Owens et al., 1991, Bailey et al., 1996, Walburger et al., 2000, and Porath et al. 2002). The interaction of each of the environmental factors, and the degree to which each factor affects distribution are similar across varying landscapes, but vary slightly on a site specific basis.

Management options such as fencing, offstream water, strategic placement of mineral, improvement of trails, season of use, and herding have been shown as effective ways to alter distribution in order to promote sustainability (Skovlin, 1965, Cook 1965, Bryant 1982, Roath and Krueger 1982, Parsons et al., 2000, and Porath et al. 2002). It is often recommended that a combination of management options be utilized in order meet management goals for individual management situations.

The direct influence of the age of cattle has also been studied (Neville, 1971, Bryant, 1982, Ralphs and Cheney, 1993, Cazcarra and Petit, 1995, Beaver and Olson, 1997, and Morrison et al., 2003). However, the majority of the studies involving cow age as a direct factor influencing grazing behavior and distribution examined the effects of classes of livestock, i.e., yearlings versus mature cow - calf pairs, or young cows versus mature cows. It is the intent of this study to assess the influence of age on a finer scale, by analyzing grazing behavior and distribution patterns of individual age classes of cattle.

Materials and Methods

Study Area

The study was conducted at the USDA, Forest Service Starkey Experimental Forest and Range, hereafter referred to as Starkey (figure 2.1). Starkey is located approximately 45 Km southwest of La Grande, Oregon, consisting of 10,102 Ha of typical northeastern Oregon mixed conifer forested rangelands, enclosed by a 2.3 m New Zealand game proof fence (figure 2.2) (Skovlin 1991, Rowland et al. 1997). Within the perimeter of the game fence, cattle fences divide the area into four main pastures, Smith-Balley, Halfmoon, Bear and Campbell, (figure 2.3) which are grazed in common by approximately 500 head of cow calf pairs each grazing season (June-October), 100 of which are property of Oregon State University's Eastern Oregon Agricultural Research Center, Union, OR. The remaining 400 head of the cattle are privately owned.

The pastures are grazed on a four pasture deferred rotational grazing system. On even numbered years (i.e., 2000), grazing is initiated in Campbell pasture and rotated through the system, ending in Smith-Balley pasture. The reverse is

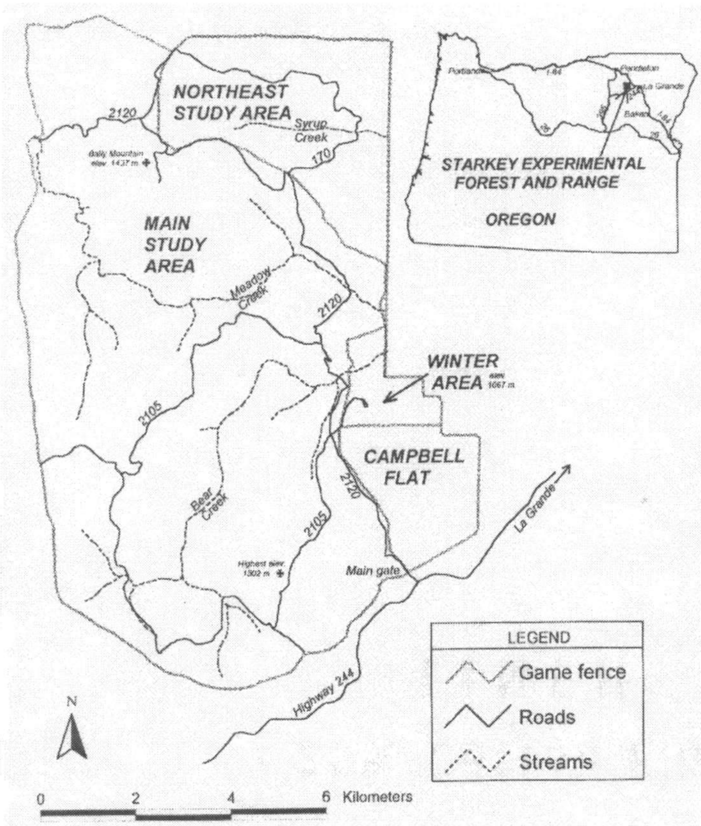

Figure 2.1. Starkey Experimental Forest and Range, northeast Oregon (Oregon Department of Fish and Wildlife, 2000)

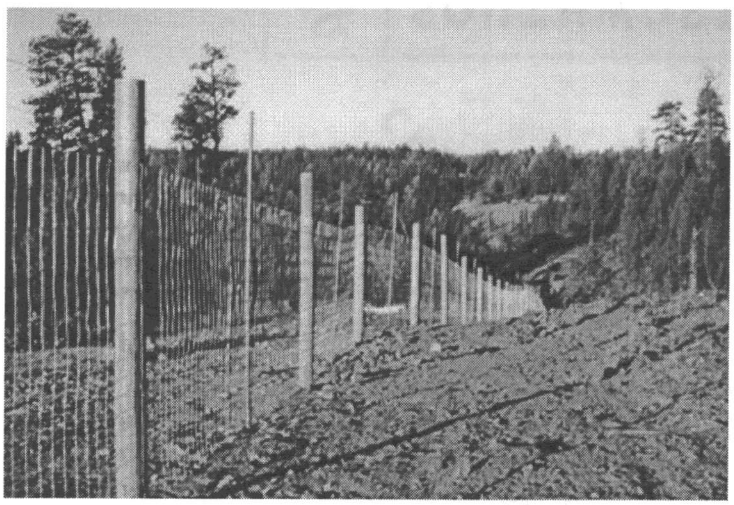

Figure 2.2. Ungulate proof fence at Starkey Experimental Forest and Range, northeast Oregon (Oregon Department of Fish and Wildlife, 1987)

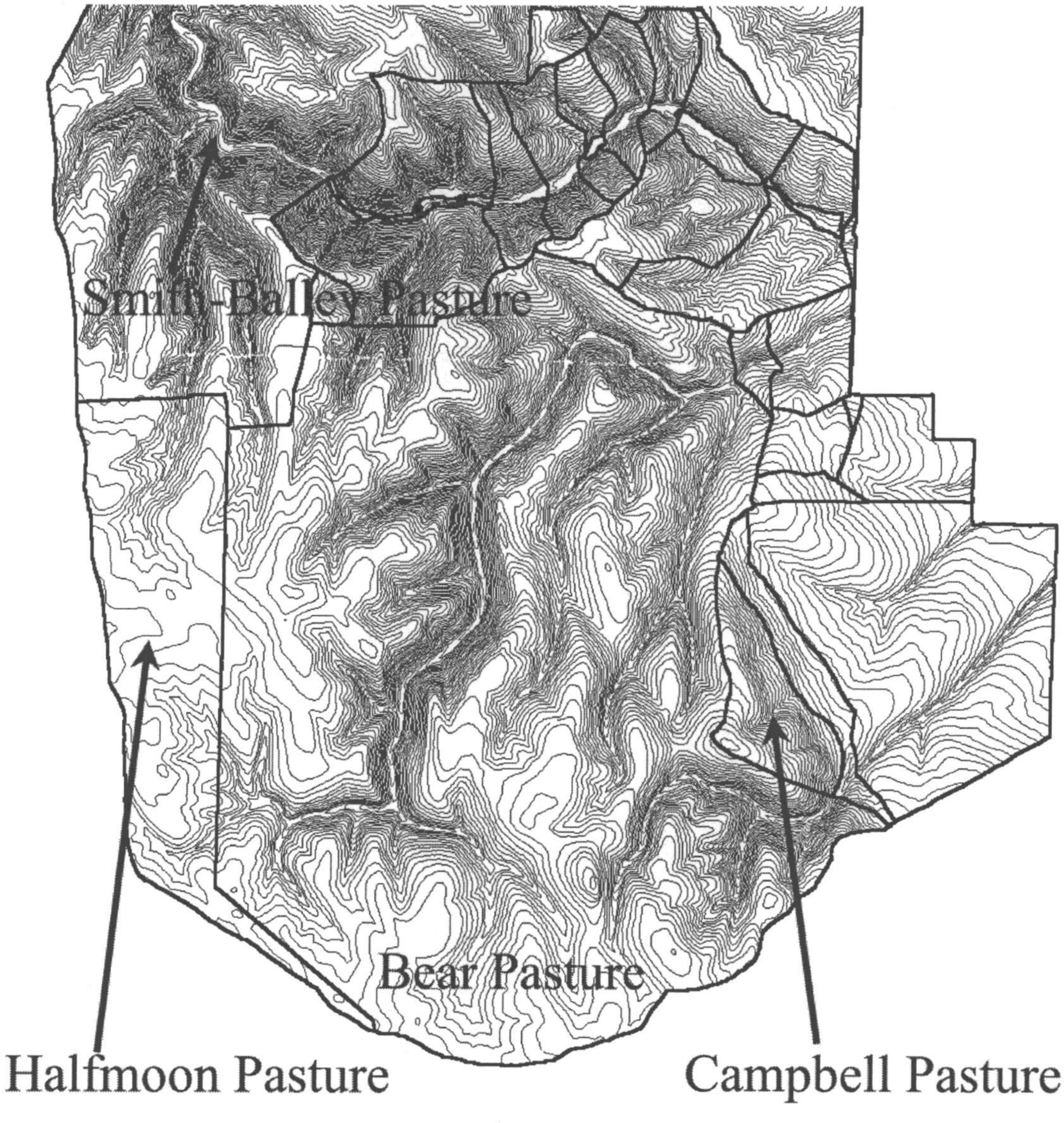

Figure 2.3. Smith-Balley, Halfmoon, Bear and Campbell pastures, Starkey Experimental Forest and Range (Wells, 2003)

conducted on odd numbered years (i.e., 2001), with grazing starting in Smith-Balley and concluding in Campbell pasture (Rowland et al. 1997).

Due to its placement in the rotation, Bear pasture was chosen for distribution analysis. Cattle graze Bear pasture within approximately three weeks of the same time period each year. Cattle graze Bear pasture for approximately six weeks each grazing season before being rotated to another pasture.

Bear pasture is comprised of approximately 3300 hectares encompassing a wide array of landscape characteristics. The pasture ranges in elevation from 1170 to 1500 meters with a mean elevation of 1395 meters (table 2.1). Lush riparian areas dominate lower elevations with wide expanses of scabland in the upland areas. In addition, large areas of forested rangeland are interspersed throughout the pasture. Average slope of Bear pasture is 17 percent with some slopes reaching a 60-degree incline, while riparian areas as well as some upland and ridge top areas are moderately flat. Within this diverse landscape, forage production varies as well, ranging from an estimated 1400 Kg/Ha to zero Kg/Ha with a mean pasture wide forage production estimate of 324 Kg/Ha.

In 1989, a Loran C radio telemetry system was installed at Starkey to study the interaction between deer, elk and cattle. The system utilizes radio collars placed on individual animals to generate locations of each animal. A total of twenty test collars (ten elk and ten cattle) were collared in 1989. After two years of successful testing, the system became operational in 1991 (Rowland et al. 1997). There are approximately 180 collars placed on animals each year (60 cows, 60 elk and 60 deer). The number of active collars varies from year to year due to availability of

Table 2.1. Habitat Variables of Interest, Bear Pasture, Starkey Experimental Forest and Range

Habitat Variable	*Mean*	*Minimum*	*Maximum*
Slope (%)	17	0	60
Sine of Aspect (neg no. = west, pos no. = east)	0.07	-1	1
Cosine of Aspect (neg no. = south, pos no. = north)	0.15	-1	1
Elevation (meters)	1395	1170	1500
Convexity (neg no. = concave, pos no. = convex)	500	473	518
Forage Production (kg/ha)	324	0	1400
Soil Depth of the A and B Horizons(cm)	27	9	55
Distance to Nearest Pixel With > 40 % cover (m)	103	0	806
Cattle Distance to Water (m)	206	0	1188
Distance to Cattle Fence (m)	977	0	3224
Canopy Closure of Trees > 12 cm dbh (%)	28	0	85

functional collars from the previous monitoring year. Extreme care was taken to insure that cattle that were fitted with a telemetry collar one year were also fitted with a collar the next year. However, this was not always feasible, because varying numbers of collars were available for placement on the cattle each year. In addition, some cows that had previously been fitted with a telemetry collar were culled from the herd for reasons of herd management.

Each collar is individually numbered and is specific to an individual animal. The Loran C system continually queries each collar in sequence every fifteen seconds. If the collar does not respond, it is queried again. Two attempts are made for each collar, before the system advances to the next radio collar. This results in completion of the collar query every 45 to 90 minutes.

As each collar is located, it emits a signal that is received by one of seven antennas located throughout the forest. These antennas in turn, return the signal to the base station computer, which stores, analyzes and generates locations of the animals, which are accurate to within 53 meters (SE = 5.9; Findholt et al. 1996).

Cattle locations have been recorded each grazing season and stored in the Starkey database from 1991 through the 2002 grazing season. Data for the ten-year period of 1991 through 2001 was utilized in assessing the influence of age on distribution of cattle. There are approximately 96,000 individual cattle locations between 1991 and 2001. The ages of collared cattle in the herd range from two to sixteen years of age.

For each individual location, a Universal Trans Mercator (UTM) coordinate has been generated, as well as time of day, and date. Habitat characteristics of Starkey have been determined on a 30 by 30 meter pixel grid, through an extensive process of aerial photo interpretation, satellite interpretation, and intensive field data collection.

In essence, for every 30 by 30 meter section of terrain at Starkey, there are in excess of 100 variables describing that particular site (Rowland et al. 1998).

Although over 100 attributes have been compiled for each pixel, twelve variables, based on available literature, have been selected to represent each recorded UTM coordinate table 2.1. Recorded features include percent slope, sine of aspect, cosine of aspect, convexity, distance to water (m), forage production (kg/Ha), distance to cover (m), elevation (m), distance to cattle fence (m), size of canopy greater than size class three, and soil depth (cm).

Sine of aspect is a measurement of the east or west aspect of the pixel. It is expressed on a scale of negative one to positive one. Values of zero indicate no aspect or a neutral value. Negative values indicate a west facing aspect, while positive values convey an east facing aspect. Cosine of aspect is expressed on the same scale as well, with negative values indicating south facing aspects, and positive values indicating a north aspect of the pixel. Values of convexity are also based on a similar scale. Negative values indicate the shape of the pixel is concave, while positive numbers are the result of the pixel displacing a convex surface.

Study Design

Cattle were sorted into age classes in order to accurately analyze differences in distribution habits. Four age classes have been established and cattle sorted accordingly. Prior to placement into the appropriate age class, cattle were screened according to the number of locations recorded for each individual. Only cattle with 50 or greater locations (Johnson et al. 2000) were sorted into the appropriate age class. Age class one cattle consists of two and three year old cattle. Age class two is comprised of four and five year old cattle. Age class three consists of six and seven year old cattle. And age class four cattle are those that are eight years and older. Cattle will hereafter be referred to by their appropriate age class designation, i.e. age class one rather than their individual ages.

Locations of cattle were recorded on a 24-hour basis. However, the locations utilized in this study were selected to reflect peak grazing hours of cattle. Locations utilized in analysis were limited to those that occurred one hour prior to sunrise, four hours after sunrise, four hours prior to sundown and one hour after sundown (table 2.2), (Parsons et al. 2000,Porath et al. 2002, Morrison et al. 2003,).

Table 2.2. Cattle Observation Totals by Age Class

Age Class	*Total Number of Cattle*	*Total Observations*	*Peak Grazing Observations*
1	72	17,409	7,762
2	92	33,247	14,871
3	57	21,545	9,759
4	48	23,956	10,647

Statistical Analysis

Resource Selection Function (RSF) was calculated for each age class of cattle. Logistic regression (PROC GENMOD, SAS Institute 1997) was used in a stepwise backwards approach to identify the variables to include in the RSF for each age class of cattle. The variance from PROC GENMOD was underestimated, because it was based on number of locations for each animal. Therefore, a jackknife procedure (Johnson et al. 2000, Coe et al. 2001) was used to test the significance of the coefficients. A different animal was sequentially dropped from the analysis after each iteration, and the analysis re-ran.

For example, in our case, 72 animals were included in age class one. The model calculated the coefficients for each variable 72 times, using the locations of 71 animals in each iteration. The resulting coefficients were accumulated and the variance of each variable was analyzed for significance ($P<0.05$) with Wald X^2 tests.

Starting with all 12 variables, we removed the 1 or 2 variables with the highest P value from the model after each iteration. This process was repeated until the remaining variables were significant ($P>0.05$). The resource selection function probability for each of the 38,213 pixels present in Bear pasture was then calculated as $RSF = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots + \beta_n x_n)$ using the nonstandardized coefficients of the significant variables (Johnson et al. 2000, Coe et al. 2001).

Resource Selection Functions were estimated for each age class of cattle, and final significant coefficients were standardized to facilitate comparisons between age classes. In addition, all comparisons between age classes were conducted, by including the Resource Selection Function for each age class as a variable in the analysis for each of the other age classes. Age class one was compared to age classes two, three and four; as was age classes two, three and four compared to age class one. Comparisons in both directions were necessary because different variables were significant in each Resource Selection Function for each age class. Therefore, while age class one might not differ from age class two in resource selection, age class two might differ from age class one in the variables driving resource selection.

Because Resource Selection Functions for each age class were comprised of several variables, the variables included in the model for age class one was eliminated from the model statement in PROC GENMOD when compared to age class two. After which, the initial procedure of logistic regression in a stepwise backwards approach was re-run. This procedure was repeated for each age class by age class comparison accordingly.

In conjunction with resource selection functions, mean values for each variable, (slope, aspect etc.) utilized in the analysis were also calculated for use in conjunction with resource selection functions to graphically display the characteristics of the significant variables in analysis.

Results

Resource Selection Function (RSF)

Initial analysis indicated that year was not a significant factor influencing distribution; therefore, results are compiled from all years (1991-2001), for cattle meeting *a priori* screening criteria. Comparison of resource selection functions for each age class of animals revealed commonalities, as well as distinct differences in the variables that were significant determinants in resource selection (table 2.3). Standardized ß's of the habitat variables that are negative indicate cattle are not selecting for resource areas that displace the habitat variable in question. For example, a negative β for the habitat variable of slope indicates cattle are selecting resource areas with lower percentages of slope.

Table 2.3. Variables and subsequent standardized coefficients in models of resource selection function of age classes of cattle during 1991-2001 grazing season, Starkey Experimental Forest and Range

	Age Class of Cattle									
	All Cattle		Age Class 1		Age Class 2		Age Class 3		Age Class 4	
	Stand. β	S.E	Stand. β	S.E.	Stand. β	S.E.	Stand. β	S.E.	Stand. β	S.E
Intercept	-1.9199	0.07	-3.6321	0.07	-2.9805	0.05	-3.4265	0.06	-3.4081	0.11
Slope	-0.1049	0.02	-0.1176	0.04	N.S.	N.S.	-0.1934	0.06	-0.0968	0.04
Sine of Aspect	-0.1154	0.01	-0.1017	0.02	-0.1247	0.02	-0.1079	0.02	-0.1174	0.02
Cosine of Aspect	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Elevation	N.S.	N.S.	-0.2769	0.07	N.S.	N.S.	N.S.	N.S.	0.2005	0.09
Convexity	-0.0499	0.01	N.S.	N.S.	N.S.	N.S.	-0.0667	0.02	-0.1059	0.03
Forage Prod	0.1383	0.01	0.149	0.01	0.1411	0.01	0.1097	0.01	0.1239	0.01
Soil Depth	N.S.	N.S.	-0.048	0.02	N.S.	N.S.	N.S.	N.S.	N.S.	N.S
Distance to Cover	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Distance to Water	0.3364	0.02	0.3111	0.03	0.372	0.02	0.2964	0.03	0.3371	0.04
Distance to Cattle Fnc	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Canopy > 12 cm dbh	-0.0562	0.01	N.S.	N.S.	-0.0621	0.01	-0.05	0.02	-0.0642	0.02

$P<0.05$ for all coefficients
N.S. indicates the variable was not significant in resource selection for that age class of cattle

Individual RSF's were calculated for each of the four age classes of animals, as well as a general cow model (GCM) RSF for cattle as a species. The general cow model RSF is comprised from all available age class data during the defined time period.

General Cow Model (GCM)

Analysis of the RSF for the General Cow Model (GCM) indicated that percent slope, sine of aspect convexity, forage production, distance to water, and canopy > class three as determinant variables in resource selection. Of the significant variables in resource selection, only forage production and distance to water were positive.

Age Class One Model (AC1M)

Results of the RSF for age class one cattle were similar to those of the GCM. Again percent slope, sine of aspect, forage production and distance to water were significant variables in the resource selection. In addition, elevation and soil depth were significant in the AC1M, while canopy > class three was not. As was the case in the GCM, only forage production and distance to water were positive habitat variables.

Age Class Two Model (AC2M)

Habitat variables found to be determinant in resource selection in the AC2M showed similar patterns to the GCM. Sine of aspect, forage production, distance to water, and, canopy > class three, were significant habitat variables in the AC2M. Once again, only forage production and distance to water were positive in nature. Convexity as well as percent slope were not significant in the AC2M as they were in the GCM.

Age Class Three Model (AC3M)

Significant habitat variables in resource selection for cattle in age class three were similar to that of the GCM. Percent slope, sine of aspect, convexity, forage production, distance to water, and canopy > class three were key determinants in resource selection. As in all prior cases, only distance to water and forage production were positive.

Age Class Four Model (AC4M)

Habitat variables determining resource selection in age class four cattle were also similar to those in the GCM. Significant habitat variables in the AC4M were percent slope, sine of aspect, elevation, convexity, forage production, distance to water, and canopy > class three. Elevation, forage production and distance to water displayed positive standardized β's in the AC4M.

Intraspecific Models (IM)

Resource selection functions for each age class of cattle were analyzed for differences in resource selection (table 2.4). Positive coefficients indicate no statistical differences between age classes of cattle. Additionally, all coefficients were approximately of the same value. Comparisons were conducted bilaterally due to the differences in habitat variables that comprised the resource selection function for each age class.

Table 2.4. Contrasts of Intraspecific models of resource selection of differing age classes of cattle in Bear Pasture, Starkey Experimental Forest and Range

	Age Class of Cattle				
	Standardized β				
Contrast	Age Class 1	Age Class 2	Age Class 3	Age Class 4	S.E.
Age Class 1 vs. 2		0.24			0.02
Age Class 1 vs. 3			0.31		0.02
Age Class 1 vs. 4				0.21	0.03
Age Class 2 vs. 1	0.27				0.02
Age Class 2 vs. 3			0.32		0.02
Age Class 2 vs. 4				0.29	0.03
Age Class 3 vs. 1	0.22				0.03
Age Class 3 vs. 2		0.22			0.02
Age Class 3 vs. 4				0.30	0.03
Age Class 4 vs. 1	0.21				0.03
Age Class 4 vs. 2		0.25			0.03
Age Class 4 vs. 3			0.32		0.03

Discussion

By employing the use of resource selection functions, determination of the influence of differing habitat variables on distribution was quantified. Two distinct habitat variables, forage production and distance to water, (table 2.3) were significant in all resource selection functions. These results are congruent to those found by previous studies (Cook 1965, Mueggler 1965, Roath and Krueger 1982, Senft et al. 1985, Owens et al. 1991, Bailey et al. 1996, Kie and Boroski 1996, Walburger et al. 2000, and Porath et al. 2002), that distance to water and available forage are key determinants in distribution.

Mean distance to water of cattle during peak grazing hours was determined (PROC MEANS, SAS Institute 1997) (figure 2.4). The results demonstrate resource selection function regarding the importance of water.

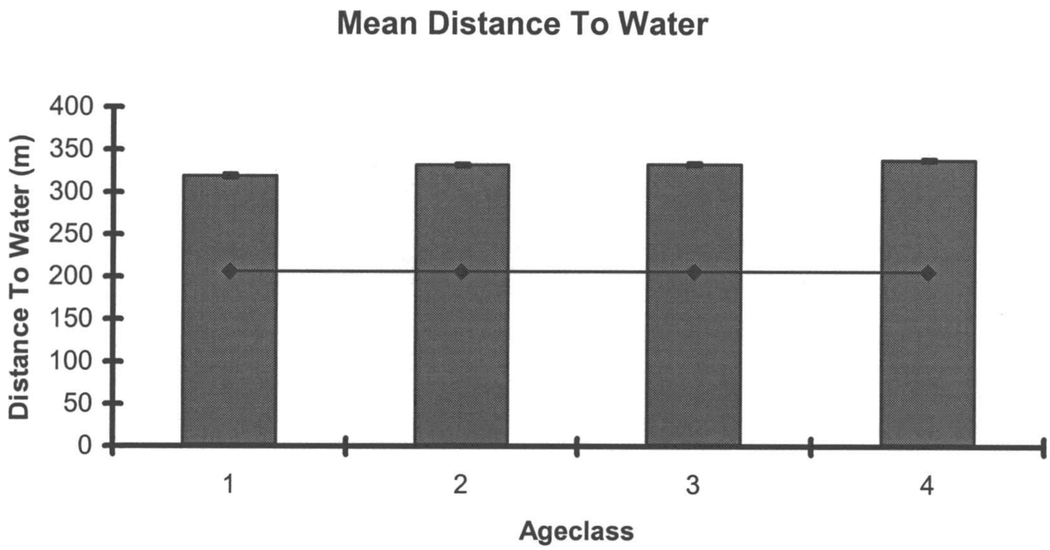

Figure 2.4. Mean distance (m), of cattle in each age class, to class 1 and 3 streams. Solid line indicates mean distance (206 meters) to water from any pixel within Bear Pasture, Starkey Experimental Forest and Range. Standard Errors ranged from 2.2 to3.0.

The standardized coefficients for distance to water are positive for each age class of cattle. As previously stated, positive coefficients indicate greater values in regard to the habitat variable in question. In the case of distance to water, a positive coefficient indicates cattle are choosing areas away from water, as demonstrated in figure 2.4. Cattle occupied areas farther from water than the mean distance to water in the pasture. Had the standardized coefficient been negative, distances in figure 2.4 would have been closer or of lower value than the mean distance to water in the pasture.

As the case with distance to water, forage production was a significant habitat variable in each resource selection function of all age classes of cattle (table 2.3). This is graphically represented in figure 2.5. Cattle of all age classes occupied areas with higher forage production than the mean value of the pasture. Although average forage production for each age class is statistically different from that of the mean value of the pasture, biologically, the maximum difference between areas occupied by age class one cattle and the mean value of the pasture differ by les than 25 kg/ha. It is interesting to note the linear decrease in forage production values as cow age increases.

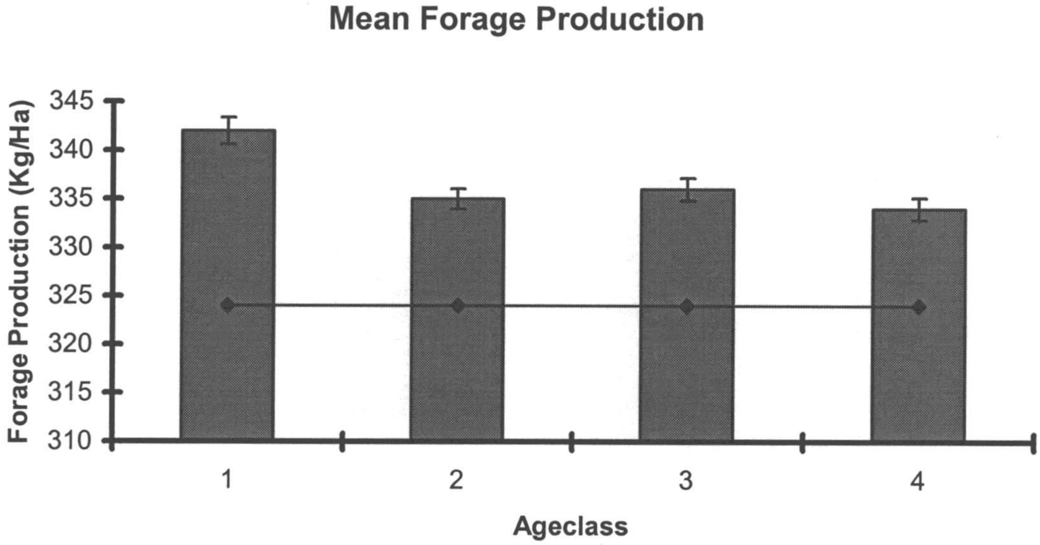

Figure 2.5. Mean forage production (kg/ha) of areas occupied by cattle in each age class during peak grazing hours, Bear Pasture, Starkey Experimental Forest and Range. Mean forage production (324 kg/ha) is represented by the solid horizontal line. Standard errors ranged from 1.0 to 1.3

Sine of aspect was also significant in the resource selection function of all age classes of cattle (table 2.3). However in the case of sine of aspect, the standardized coefficient was negative indicating preference to west facing slopes. Figure 2.6 illustrates the results of the resource selection function. All values are negative or a value lower than the mean value of sine of aspect in the pasture (table 2.1). Sheehy and Vavra (1996) concluded that cattle utilized areas encompassing all aspects, suggesting that available forage found on varying aspects was the primary factor influencing distribution. As previously stated, cattle were choosing areas of higher forage production, in the case of this pasture, west facing slopes.

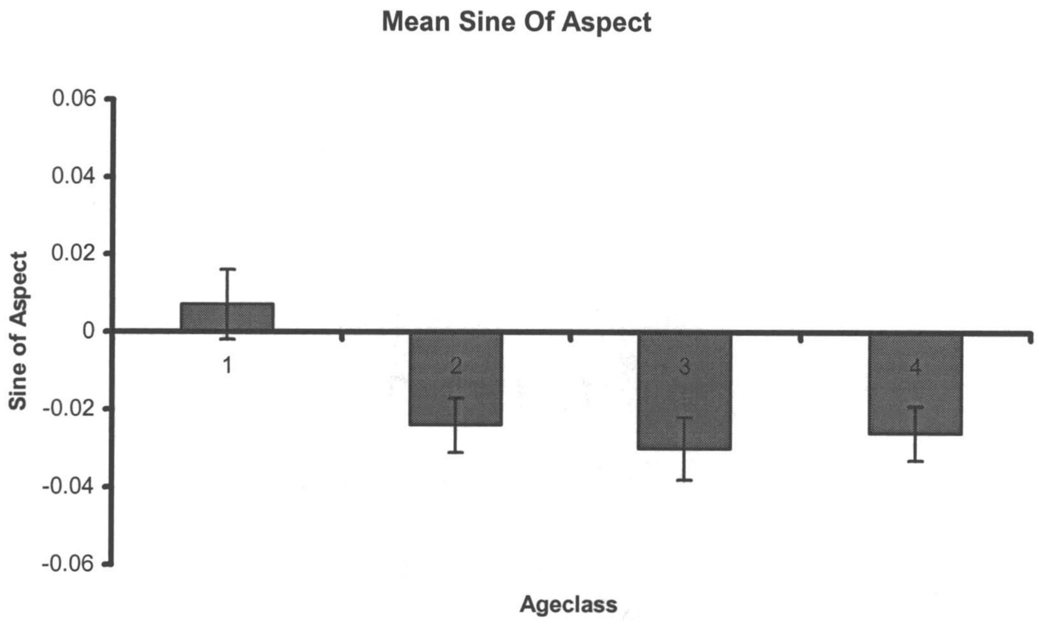

Figure 2.6. Sine of aspect utilized for each age class of cattle. Negative values indicate westerly aspects, positive values indicate easterly aspects. Bear Pasture, Starkey Experimental Forest and Range. Standard Error ranges from 0.007 to 0.009.

Slope percentage was significant in age class one, three and four resource selection functions (table 2.3). All standardized coefficients were negative, indicating lower percent slopes. This is again graphically demonstrated (figure 2.7). Note that mean slope use by all cattle is lower than the mean value of slope found in the pasture. This is again in concurrence with the findings of previous studies. Mueggler (1965) determined relative time spent at different distances upslope on areas of varying steepness. Results from this study are similar to those of Mueggler. Assuming the mean distance to water of cattle was 325 meters, and mean slope use of all cattle was fourteen percent, according to Mueggler, cattle should spend approximately eight hours of the day in that habitat, while cattle in this study occupied the area approximately ten hours of the day. Bryant (1982), and Gillen et al. (1984) reported that cattle utilized areas of slope less than 35 and 20 percent respectively, which concurs with our assessment.

Ganskopp and Vavra (1987) demonstrated the preference of cattle to slopes of 0 to 9 percent, and aversion to slopes greater than 20 percent. However, in the more rugged pasture, slope use was found in areas of 30 to 39 percent. This indicates, that if the slope of the available terrain is steep, some use will occur. We can conclude, due to the negative coefficients associated with slope, cattle were selecting habitats of similar slope.

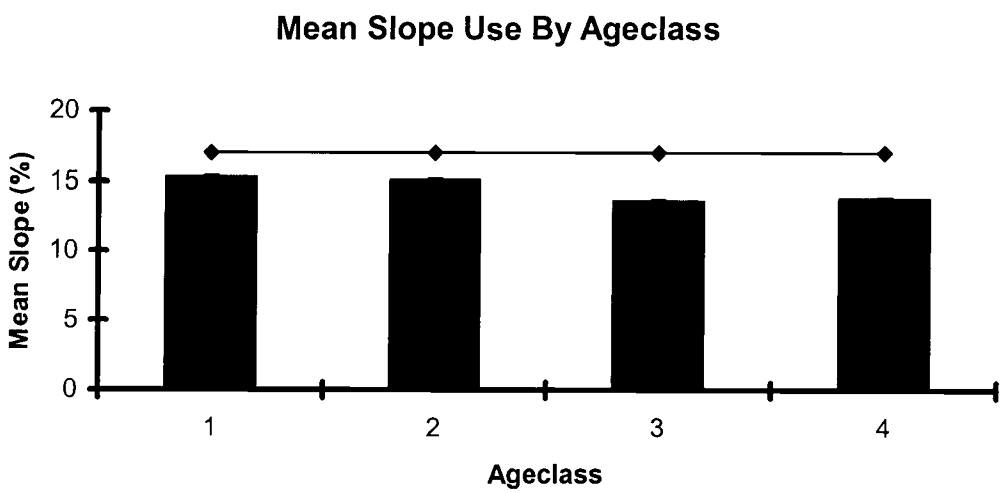

Figure 2.7. Mean slope use of cattle of differing age classes during peak grazing hours. Solid horizontal line indicates the mean slope of Bear Pasture, Starkey Experimental Forest and Range. Standard Errors ranged from 0.09 to 0.12

Canopy closure percentage of trees greater than 12 cm dbh, was significant in the resource selection of cattle in age classes two, three and four (table 2.3), with standardized coefficients in each of the age classes of cattle were negative, indicating cattle in all age classes were utilizing areas away from cover during peak grazing hours.

Mean values of canopy closure occupied by each age class were the same with a value of 26 percent for each age class during grazing hours. Mean canopy closure of trees greater than 12 cm dbh in Bear Pasture is slightly greater at 28 percent (table 2.1). Although distance to cover was not significant in any of the resource selection functions, the percent canopy cover was.

Miller and Krueger (1976) reported that canopy cover (%) in conjunction with distance to water and soil depth, were highly correlated with utilization. Areas of lower canopy cover generally produce greater levels of understory production. This is affirmed in the context of this study as well. Positive standardized coefficients for forage production in conjunction with negative standardized coefficients for canopy closure greater than 12 cm dbh indicates that cattle are selecting areas higher in forage production than the mean levels of production in areas with lower percentage of canopy closure.

Elevation was significant in resource selection functions in only two of the four age classes of cattle. Cattle in age class one displayed a negative standardized coefficient, while cattle in age class four were opposite, indicated by the positive sign of the standardized coefficient. Both coefficients are quite determinative in resource selection function, displacing approximately the same level of influence on selection as distance to water (table 2.3).

Higher elevations, especially in Bear Pasture, which is characterized by deep riparian areas and large flat upland areas, are often thought to be a greater distance from lowland or riparian areas. This is affirmed be figure 2.4 which indicates that cattle in age class four (eight years of age and older) were, on average, farther from water than cattle in age class one, due to occupancy of areas of higher elevation.

Examination of figure 2.8 graphically reflects the influence of elevation on distribution. Age class one cattle appear to prefer areas of lower elevation, while age class four cattle, are selecting for areas that are higher in elevation than the mean elevation for that pasture, which corresponds directly with resource selection function estimations.

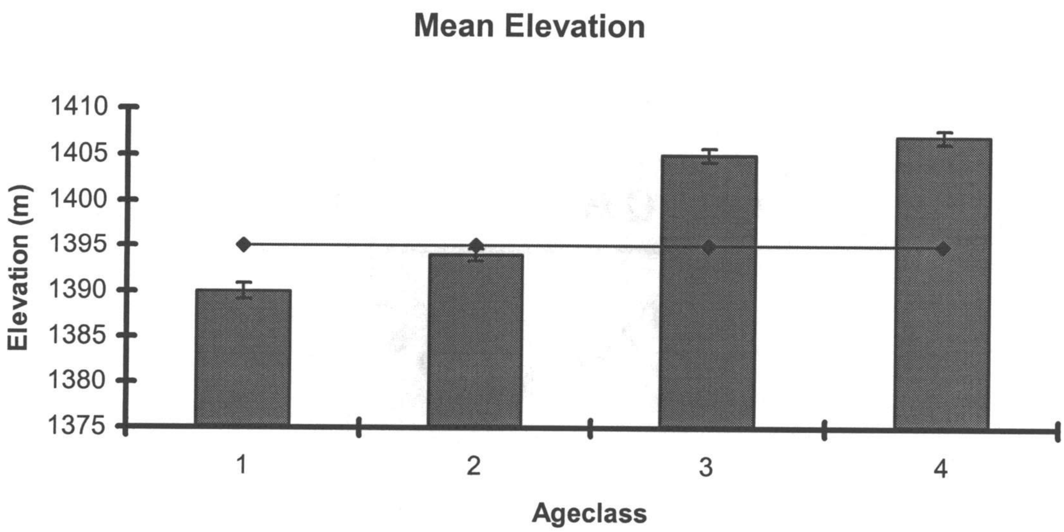

Figure 2.8. Mean elevation of areas occupied by each age class of cattle during peak grazing hours. Horizontal line indicates the mean elevation of Bear Pasture, Starkey Experimental Forest and Range. Standard Errors ranged from 0.6 to 0.8.

Morrison et al. (2003) demonstrated that cattle of older ages distributed farther from water and preferred the upland areas than first calf heifers. Considering the strong differences in sign displaced by the standardized coefficients, the same holds true in this case.

Beaver and Olson (1996) concluded that three-year-old cattle were less efficient at using a pasture's forage as well as thermal resources than seven and eight year old cattle. Again, our results confirm their findings. Sheehy and Vavra (1996) indicated that elevation was influencing cattle and elk selection significantly, due to changes in plant community structure at differing elevations. It is apparent that differences in vegetation due to elevational gradients are present here as well. Resource selection functions did not statistically differ between age classes of cattle (table 2.4). However, it is apparent that differences in distribution patterns are present. Younger cattle (age class one) utilize areas lower in elevation, higher in forage production, and closer to water, while older cattle (age class four) are using areas farther from the riparian area, which are lower in levels of forage production.

Neville (1971) concluded that while body weights showed significant increases up to six years of age, there was no indication that energy requirements differed with age. However, Hunter and Siebert (1986) demonstrated that with increasing age and live weight of steers, intake per unit of body weight declined. Cazcarra and Petit (1995) determined herbage intake (per kg live weight) were lowest for mature cows and highest for heifers. Although intake and body weight were not determined within the confines of this study, it would stand to reason cattle in age class four have lower energy requirements, as well as greater amounts of experience (Bailey et al 1996) on this pasture, therefore they distribute to a more optimal degree than cattle in age class one

It can only be speculated that cattle in age class four utilized areas higher in elevation, with lower levels of forage production, that were located farther from water, due only to age. The direct influence of experience was not quantified in this experiment. However, there remains a high degree of potential for future experimentation regarding the direct influence of experience on distribution and grazing patterns.

Howery et al. (1996) determined that culling cattle that spend disproportionate amounts of time in riparian areas from the herd could improve distribution patterns as a whole. Morrison et al. (2003) concluded that older cattle distributed to a greater degree than young cattle. Porath et al. (2002) demonstrated utilization of off stream water and supplementation alters distribution, regardless of age. In addition, Parsons et al. (2000) determined desired utilization was most attainable with early season grazing.

Implications

Our results indicate that age of cattle appears to be a determinate factor in resource selection as well. While no statistical differences between resource selection functions of differing age classes of cattle arose, a biological difference was observed. Perhaps a greater understanding of the determinant factors in distribution has been offered.

When managing for optimum distribution and subsequent utilization, resource managers and producers face a variety of challenges. While it is doubtful any single entity will choose to employ every available management option in order to optimize utilization, and thus sustainability, managers should not be expected to employ every potential management option, rather, employ the management strategy that matches their particular environmental and managerial strategies, as well as long-term production goals.

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CHAPTER 3

THE INFLUENCE OF LANDSCAPE ON THERMAL REGIMES: A COMPARISON OF RIPARIAN VS UPLAND TEMPERATURES

Micah S. Wells, Martin Vavra, Timothy DelCurto

Authors are Graduate Research Assistant, Department of Rangeland Resources, Oregon State University, Corvallis, Oregon, 97331; Professor, Department of Rangeland Resources, Eastern Oregon Agricultural Research Center, Oregon State University, Burns, Oregon, 97720; Associate Professor, Department of Animal Sciences, Oregon State University, Eastern Oregon Agricultural Research Center, Oregon State University, Union, Oregon, 97883

Abstract

The objective of this study was the quantification of the differences between ambient and black body air temperature between riparian and upland areas. In two consecutive years, 230 thermal probe stations were placed in a manner to represent the riparian and upland areas of a 3300 a pasture in the USDA Forest Service Starkey Experimental Forest and Range in northeast Oregon. Temperatures were recorded once per hour over a six -week grazing period, for each year. The trial was conducted from 5 Aug to 25 Sep in 2001, and from 15 Jul to 1 Sep in 2002. Probes ere placed at a height of one meter to simulate mid height on the body of a cow. Differences were considered significant at the $P<0.05$ level. Both year and season (early vs. late) were different ($P<0.01$) and therefore analyzed separately. For both 2001 and 2002, daily mean ambient and black body temperatures differed between riparian and upland areas ($P<0.01$), with riparian area temperatures being cooler than upland areas during the morning and evening hours. Hourly comparisons of upland and riparian area temperatures differed in morning and evening hours ($P<0.05$) but were similar during the mid day periods ($P<0.05$) for both years of the study. Black body temperatures were warmer ($P<0.05$) in both riparian and upland areas during the mid day time periods. Our research demonstrates the hourly and daily changed in landscape thermal patterns on a forested rangeland.

Keywords: Riparian, upland, ambient, temperature

Introduction

Thermal regimes on a landscape are influenced by a multitude of factors, each contributing to the resulting temperature. Altitude, aspect, solar radiation, position of the sun, time of year, time of day, wind, humidity, and spectral distribution of sunlight vary on a microclimatic level (Aussenac, 2000). Each microclimate in turn displaces individual thermal characteristics. Lowland areas are sinks for cooler denser air, resulting in diurnal thermal inversions across landscapes (Thompson and Dickson, 1958). These inversions are responsible for cool air patches and sinks in the lowland areas.

Morecroft et al. (1998) studied the air and soil microclimates of deciduous woodland compared to an open site. They found that woodland air temperatures were lower than grassland, and decreased from the canopy to the understory, in the middle of a hot sunny day. The maximum differences between woodland and grassland air temperature was approximately 3°C. Woodland soil temperatures were lower than the air temperature, and decreased with depth as well.

Thermal properties of a landscape and the resulting thermal regimes have pronounced effects on livestock. Cattle, which are homeotherms, strive to maintain a balance between the heat gained and heat released from their body, in order to maintain a core body temperature within the thermal neutral zone (TNZ). The TNZ for beef cattle is 15-25° C, with 20° C considered the optimal temperature and the baseline for correction calculations (NRC, 1981). Encompassed within the outer bounds of the thermal neutral zone are the upper and lower critical temperatures. Temperatures in excess of 25° C are considered to be in the upper critical temperature zone, while those temperatures of –21 ° C or lower fall within the lower critical temperature zone.

Ambient temperature strongly effects digestion and metabolism (NRC, 1981) in beef cows. Increases and/or decreases in ambient temperature outside of the thermal neutral zone, can have marked effects on intake. Ambient temperatures in excess of 35°C can reduce intake of cattle on full feed by as much as 35 percent. Intakes are often stimulated when temperatures fall below the thermal neutral zone, in order to maintain the energy requirements of the body.

It is hypothesized that temperatures on a landscape basis will vary greatly between riparian and upland areas through the course of hourly, daily and monthly intervals. Riparian areas will be significantly cooler in the morning hours, cooler, but to a lesser degree than upland temperatures in the mid day period, and then returning to significantly cooler in the evening hours of the day.

Materials and Methods

All studies were conducted at the Starkey Experimental Forest and Range, hereafter referred to as Starkey (figure 3.1). Starkey is located approximately 45 Km southwest of La Grande, Oregon, consisting of 10,102 ha of typical northeastern Oregon mixed conifer forested rangelands, enclosed by a 2.3 m New Zealand game proof fence (figure 3.2) (Skovlin 1991, Rowland et al. 1997). Within the perimeter of the game fence, cattle fences divide the area into four main pastures, Smith-Balley, Halfmoon, Bear and Campbell, (figure 3.3) which are grazed in common.

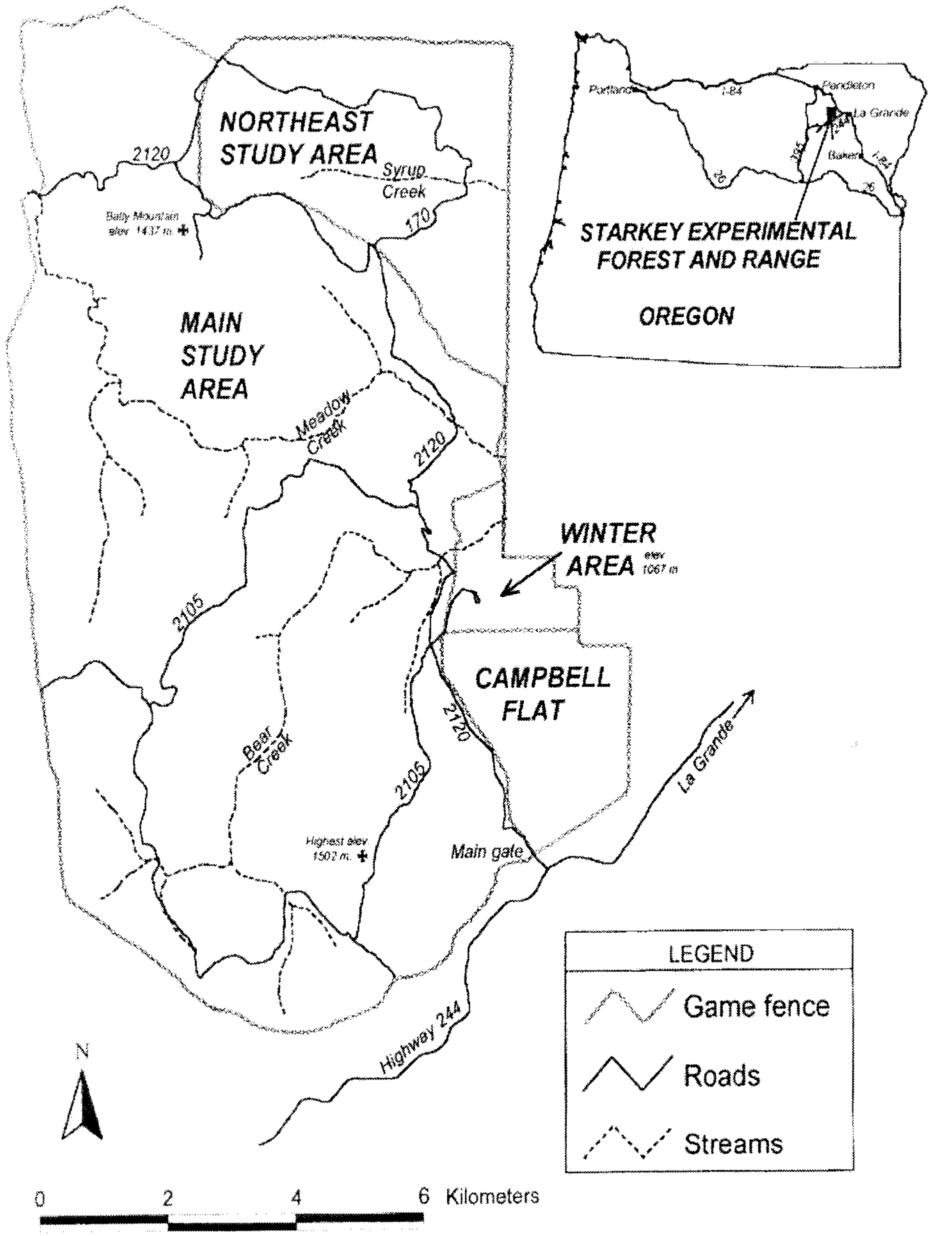

Figure 3.1. Starkey Experimental Forest and Range, northeast Oregon (Oregon Department of Fish and Wildlife, 2000)

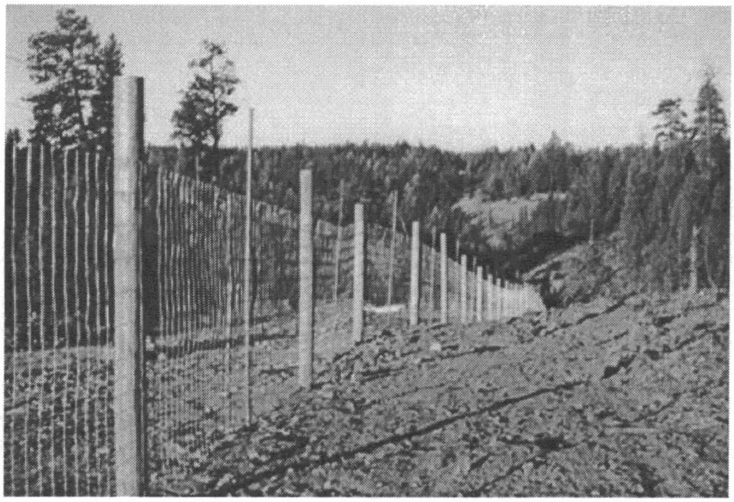

Figure 3.2. Ungulate proof fence at Starkey Experimental Forest and Range, northeast Oregon (Oregon Department of Fish and Wildlife, 1987)

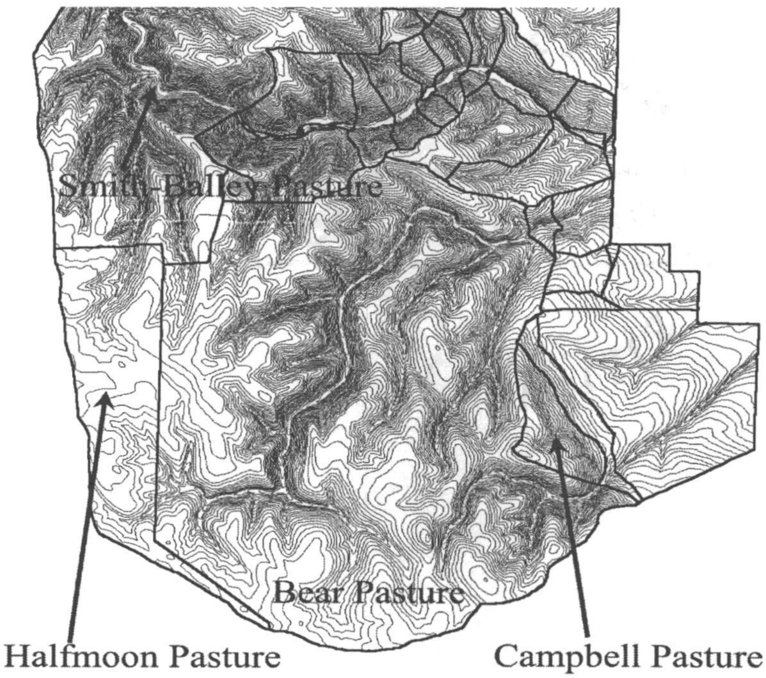

Figure 3.3. Smith-Balley, Halfmoon, Bear and Campbell pastures, Starkey Experimental Forest and Range (Wells, 2003)

Approximately 500 head of cow calf pairs graze each season (June-October), 100 of which are property of Oregon State University's Eastern Oregon Agricultural Research Center, Union, OR. The remaining 400 head of the cattle are privately owned. The pastures are grazed on a four pasture deferred rotational grazing system. On even numbered years (i.e., 2000), grazing is initiated in Campbell pasture and rotated through the system, ending in Smith-Balley pasture. The reverse is conducted on odd numbered years (i.e., 2001), with grazing starting in Smith-Balley and concluding in Campbell pasture (Rowland et al. 1997).

Due to its placement in the rotation, Bear pasture was chosen for thermal pattern analysis. Cattle graze Bear pasture within approximately three weeks of the same time period each year. Cattle graze Bear pasture for approximately six weeks each grazing season before being rotated to another pasture.

Bear pasture is comprised of approximately 3300 hectares displacing a wide array of landscape characteristics. The pasture ranges in elevation from 1170 to 1500 meters with a mean elevation of 1395 meters (table 3.1). Riparian areas dominate lower elevations with wide expanses of scabland in the upland areas. In addition, large areas of forested rangeland are interspersed throughout the pasture. Average slope of Bear pasture is 17 percent with some slopes reaching a 60-degree incline, while riparian areas as well as some upland and ridge top areas are perfectly flat. Within this diverse landscape, forage production varies as well, ranging from an estimated 1400 Kg/Ha to zero Kg/Ha with a mean pasture wide forage production estimate of 324 Kg/Ha.

Table 3.1. Habitat Variables of Interest, Bear Pasture, Starkey Experimental Forest and Range

Habitat Variable	*Mean*	*Minimum*	*Maximum*
Slope (%)	17	0	60
Sine of Aspect (neg no. = west, pos no. = east)	0.07	-1	1
Cosine of Aspect (neg no. = south, pos no. = north)	0.15	-1	1
Elevation (meters)	1395	1170	1500
Convexity (neg no. = concave, pos no. = convex)	500	473	518
Forage Production (kg/ha)	324	0	1400
Soil Depth of the A and B Horizons(cm)	27	9	55
Distance to Nearest Pixel With > 40 % cover (m)	103	0	806
Cattle Distance to Water (m)	206	0	1188
Distance to Cattle Fence (m)	977	0	3224
Canopy Closure of Trees > 12 cm dbh (%)	28	0	85

Study Design

In order to determine the various temperature regimes throughout Bear pasture, thermal probes were placed in the pasture on a grid system (figure 3.4). Upland area probes were placed every 402 meters (0.25 miles). Within Starkey, and many locations in northeastern Oregon, areas of open scabland or forested areas tend to be very large; therefore, it is possible to increase the spacing of temperature probes.

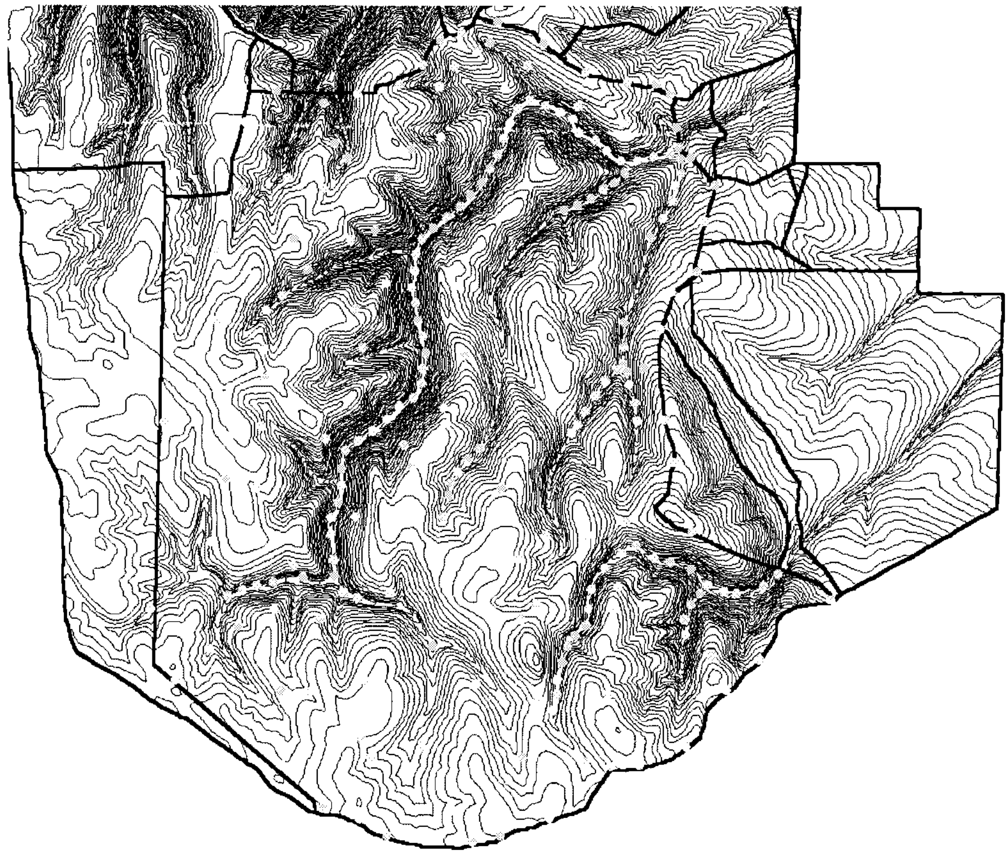

Figure 3.4. Thermal probe location s in Bear Pasture, Starkey Experimental Forest and Range

The thermal probes utilized are Kooltrak© 214002 standard temperature logger. The Kooltrak thermal probe has a resolution of .5° C with accuracy of ± 1.0° C. Effective thermal range is -20°C to +85°C with sample storage capacity of 2048 samples.

Thermal probe placement was calculated by dividing pasture size by proposed probe placement, resulting in approximately 240 thermal probe stations were required to insure adequate representation of the varying temperature regimes in the pasture. Each probe station is equipped with an ambient air temperature probe. In addition, every third probe station is equipped with a "black ball" temperature probe. Therefore, 320 total temperature probes will be placed at 240 different locations throughout Bear pasture.

Black ball temperature readings estimate equivalent temperature, which can be expressed as the sum of air temperature and a temperature increment, which is the product of a radiation term and a convection term (Mahoney and King, 1977). Rather complex models have been developed to determine this estimate, which include boundary layer resistance of the animal, ambient air temperature, wind speed, the animals' diameter parallel to the wind vector, and air temperature of the animals surface emissivity in conjunction with several pre-calculated environmental constants. In essence, the estimated thermal heat load experienced by an animal.

An alternative to these computations was shown to be a black copper ball, with a temperature probe placed inside (Bond and Kelly, 1955, Lustria et al., 1965, Kuehn et al., 1970, Bakken, 1981). Therefore, black copper balls will be employed in order to determine potential heat load experienced by animals.

Thermal probes were programmed to record temperatures every 60 minutes, throughout the six-week grazing period. All temperature probe locations were recorded using global positioning systems in order to determine exact placement within the pasture.

Statistical Analysis

Analysis was conducted using the Mixed procedure of SAS, with time considered a random variable. Least significant means were utilized to determine differences in temperatures. Differences were considered significant at the $P<0.05$ level for all analysis. Thermal probes were divided into two types within two areas; ambient and blackball, within riparian and upland areas. Analysis conducted examined the differences between riparian and upland ambient and blackball thermal probes.

Data was collected and analyzed for the years 2001 and 2002. Approximately six weeks of data was collected during each season, resulting in an excess of 350,000 temperature samples per year. Year was determined to be a significant factor ($P<0.01$), subsequently, 2001 and 2002 were analyzed separately. Each year of thermal data was further divided into three-week periods, and designated as early or late season within the year in question. Season was significant as well ($P<0.01$), and was therefore analyzed separately, resulting in the following designations: year one, early season, year one, late season, year two, early season, and year two, late season.

Daily maximum, minimum, and mean temperatures were calculated for each grazing period. Maximum and minimum temperatures were calculated and compared to upper and lower critical thermal zones (NRC, 1981). Additionally, mean, hourly temperatures for each grazing period were calculated as well.

During both years of data collection, several instances of extreme high and low temperatures were encountered. Temperature readings of 64°C and –22°C were recorded on several instances. The upper temperatures of 64°C were known not to be accurate, and were compared with available weather data from a local weather station. The lower temperatures exceeded the recording range of the thermal probe, and were also considered inaccurate.

In order to compensate for the extreme temperature incidents, 99 percent confidence intervals were calculated around mean temperatures, using PROC Means and the 99 CI procedures of SAS to determine daily temperature ranges. Less than 2000 individual temperatures were excluded from the over 700,000 temperature readings for both years when calculating the 99 percent confidence intervals.

Results

Year One, Early Season, Daily Temperatures

During the extent of the early portion of the 2001 grazing season, (5 Aug – 30 Aug) all but two days exceeded the upper limit of the thermal neutral zone (25°C), while the majority of the temperatures were at or above the upper critical zone (35°C).

Additionally, temperatures on all but two days were below the lower limit of the thermal neutral zone (15°C). Despite the high levels of fluctuation, mean daily temperatures were outside the boundaries of the thermal neutral zone on only six occasions.

Year One, Early Season, Hourly Temperatures

Ambient temperatures between riparian and upland areas were different from 0100 until 1000 ($P < 0.01$), with riparian areas at a maximum difference of 5° C cooler at 0800 (Figure 3.5). Beginning at 1100 and lasting through 1300, temperatures converged showing no difference ($P < 0.05$) between riparian and upland areas.

Temperatures again diverge, and are different ($P < 0.01$) until 1600 in the evening, when riparian and upland temperatures converge at 1700. Ambient riparian and upland temperatures again differ for the remainder of the evening hours ($P < 0.01$) until 1100.

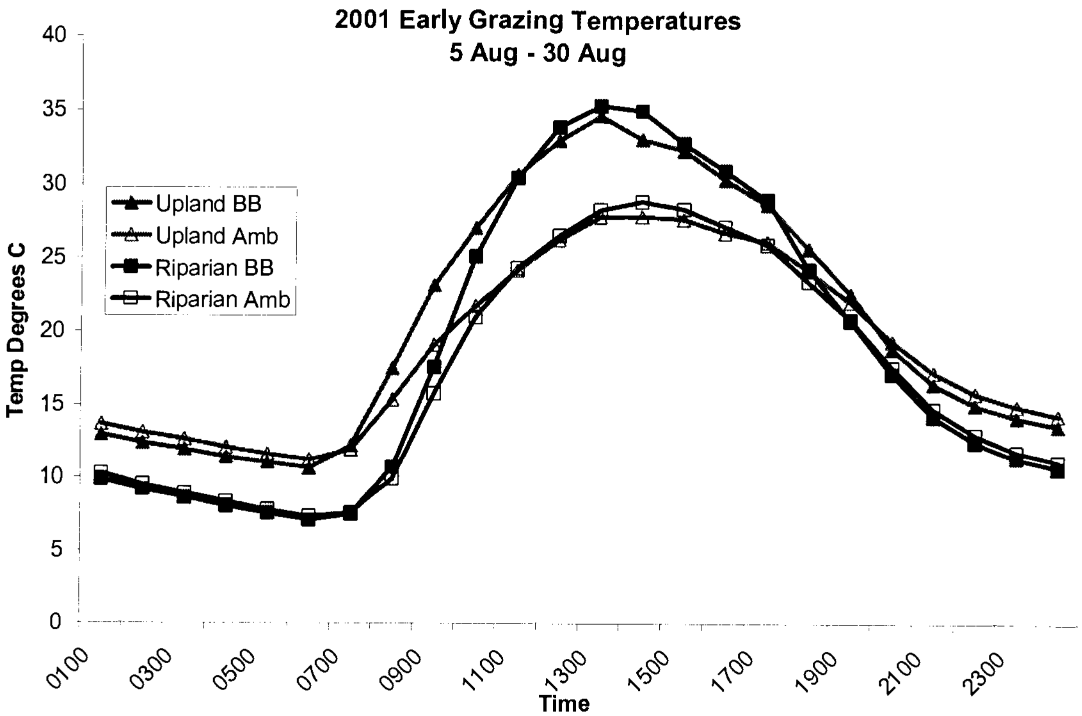

Figure 3.5. 2001 Early grazing season hourly mean temperatures (°C), Bear Pasture, Starkey Experimental Forest and Range. Standard Errors <0.2.

Year One, Late Season, Daily Temperatures

The second portion, or late season of the 2001 grazing season, (31 Aug – 25 Sep), displayed similar temperature patterns to the early portion of the grazing season. All but one day exceeded the upper limits of the thermal neutral zone (25°C), with all of the days below the upper critical limit of 35°C.

Minimum temperatures for each day were all below the lower limits of the thermal neutral zone (15°C). During this period of the grazing season, mean daily temperatures were at or below the lower limit of the thermal neutral zone of 15°C, for 15 days.

Year One, Late Season, Hourly Temperatures

The late season of year one showed similar trends to that of the early season. Ambient temperatures differed significantly ($P < 0.01$) from 0100 until 1000 between riparian and upland areas (Figure 3.6). Riparian areas were again cooler with a maximum difference of 6°C. Temperatures converged at 1100 and 1200 with no differences between riparian and upland areas ($P < 0.05$). Temperatures were again different throughout the remainder of the day, until convergence at 1100.

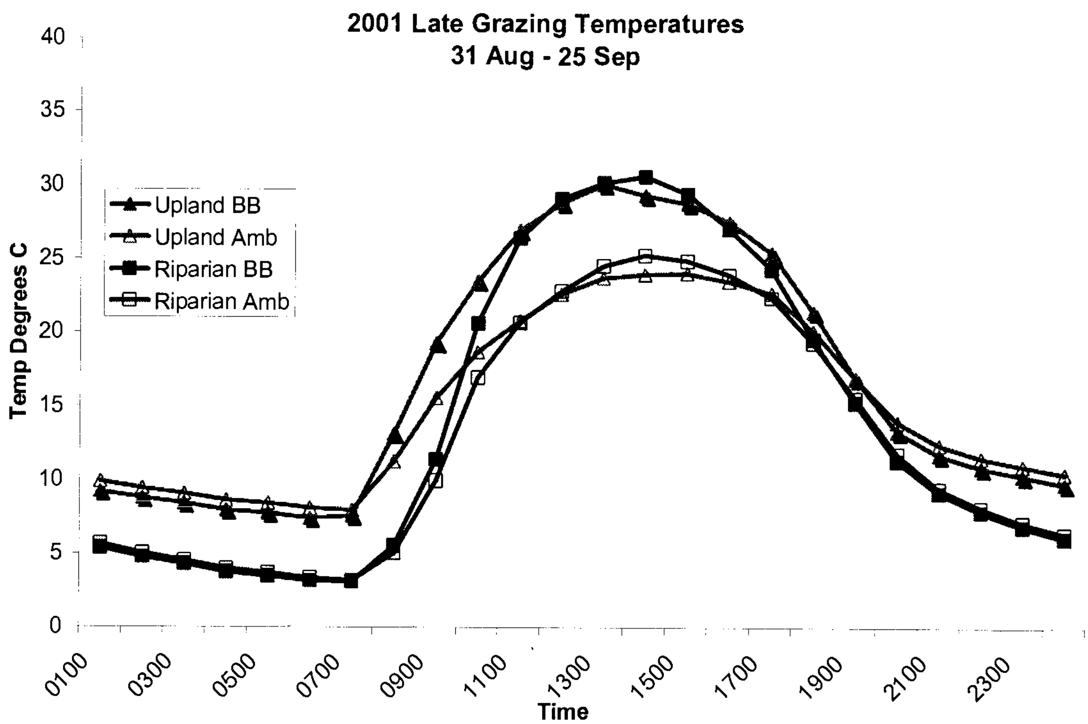

Figure 3.6. 2001 Late grazing season hourly mean temperatures (°C), Bear Pasture, Starkey Experimental Forest and Range. Standard errors <0.2.

During the early grazing season of 2002, maximum and minimum temperatures for the grazing period exceeded the upper (25°C) and lower (15°C) limits of the thermal neutral zone respectively

In the early portion of the 2002 grazing season, temperatures exceeded the upper critical limit of 35°C on three occasions. Mean daily temperatures were below the lower thermal neutral zone limit (15°C) on eight occasions.

Year Two, Early Season, Hourly Temperatures

Year two results revealed similar trends to that of year one. Ambient temperatures between riparian and upland areas were significantly different ($P<0.01$) from 0100 until 1000 (Figure 3.7). Ambient temperatures between the hours of 0100 and 1000 were significantly different ($P< 0.01$) with riparian areas displaying lower ambient temperatures than upland areas. The maximum difference between riparian and upland areas (4.9 °C) occurred at 0700. Temperatures converged between riparian and upland areas at 1100. At 1700 temperatures again diverged, between riparian and upland areas (P< 0.05). Ambient riparian and upland temperatures are again different until 1100.

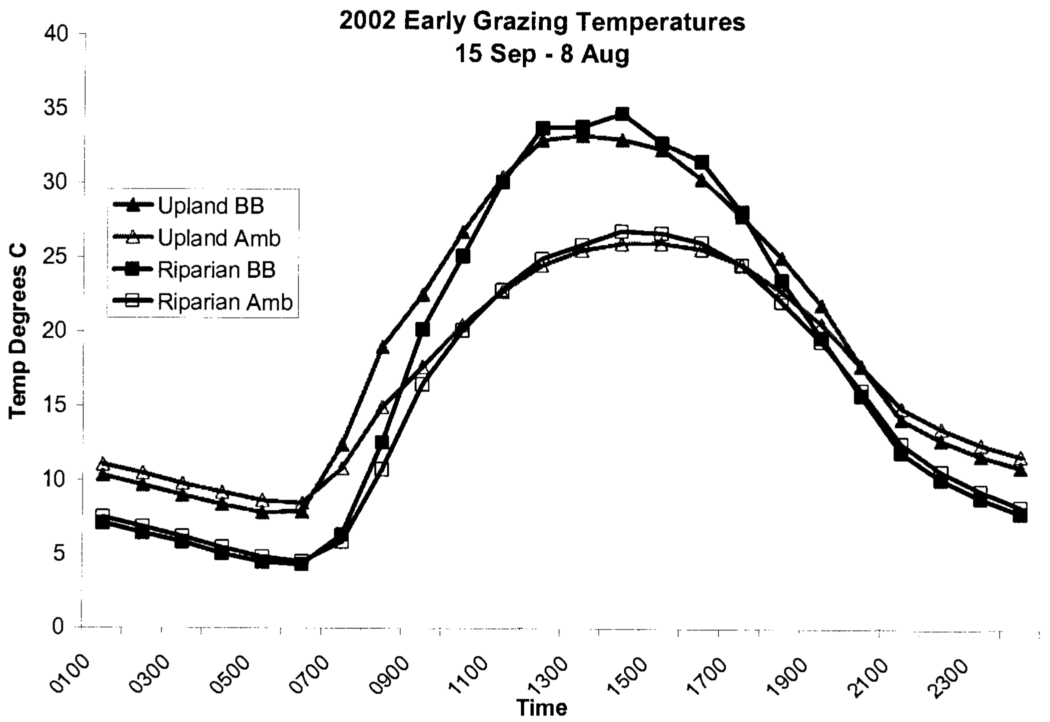

Figure 3.7. 2002 Early grazing season hourly mean temperatures (°C), Bear Pasture, Starkey Experimental Forest and Range. Standard errors <0.2

Year Two, Late Season, Daily Temperatures

Daily maximum temperatures once again all exceeded the upper limit of the thermal neutral zone (15°C). Three days exceeded the upper critical limit of 35°C. All minimum temperatures were below the lower limit of the thermal neutral zone, with mean daily temperatures falling below the limit on eight days.

Year Two, Late Season, Hourly Temperatures

Late season results mimicked earlier results. Ambient riparian and upland temperatures differed significantly between the hours of 0100 and 1000 (P< .01) with riparian areas once again showing cooler temperatures (Figure 3.8).

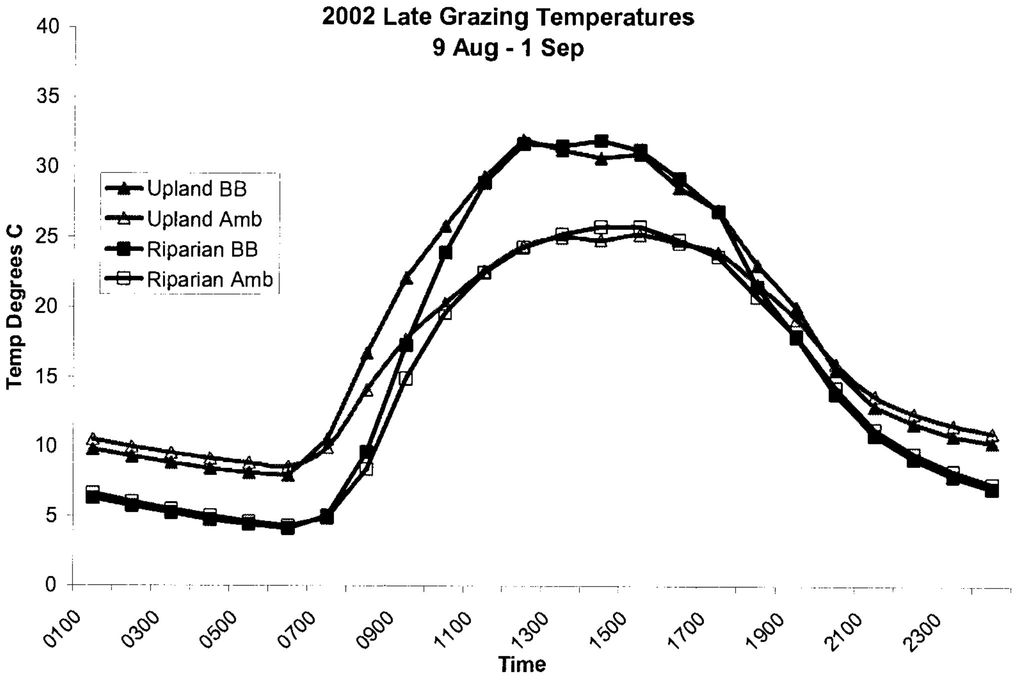

Figure 3.8. 2002 Late grazing season hourly mean temperatures (°C), Bear Pasture, Starkey Experimental Forest and Range. Standard errors <0.2

Maximum difference in ambient temperatures between riparian and upland areas was 5° C occurring at 0800. Temperatures converged and showed no difference (P< 0.05) between the hours of 1100 and 1300. Temperatures again diverged for the hours of 1400 and 1500. At 1600, ambient riparian and upland temperatures converged and were not significantly different (P< 0.05). Following the 1600 convergence, temperatures differed ($P< .01$) throughout the remainder of the day until the 1100 convergence.

Black Body Hourly Temperature

To refresh, black ball temperature readings estimate equivalent temperature, which can be expressed as the sum of air temperature and a temperature increment, which is the product of a radiation term and a convection term (Mahoney and King, 1977). In other words, it is an index of the temperature being "felt" or "experienced" by the animal.

Black body temperatures were similar for each of the grazing periods. In each of the four grazing seasons (figures 3.5, 3.6, 3.7, and 3.8) black body temperatures were the same ($P<0.05$) as ambient temperatures in the cooler morning and evening periods. As the day progressed, black ball temperatures increased at a faster rate than did ambient temperatures ($P>0.05$). During the mid-day hours, black ball temperatures differed ($P>0.05$) by approximately 10°C over ambient temperatures.

Black body rates of cooling were faster ($P>0.05$) than ambient temperatures, until convergence of the two in the evening hours. After evening convergence, black ball and ambient temperatures were the same throughout the night, until the heating period of the next day. Again, riparian and upland temperatures differed ($P>0.05$), but ambient and black body temperatures were the same ($P<0.05$) within each of the areas.

Discussion

Morecroft et al. (1998) concluded that maximum differences between woodland and grasslands were 3°C. Our results indicate maximum differences between riparian and upland areas were at least 3°C and often ranged between 5° ambient and 10°C for black ball temperatures.

A difference of ten degrees could have a heavy influence on cattle distribution. By referring to the results of hourly temperatures in this chapter, if ambient air temperatures were 25°C, black ball temperatures could easily be 35°C, which would shift the thermal environment of the animal from the thermal neutral zone to the upper critical limit (NRC, 1981).

Increasing temperatures result in increases in water consumption by cattle (NRC, 1981), which could explain the differences in distribution of cattle noted in Parsons et al. (2002), Porath et al. (2002), and Morrison et al. (2003). Cattle tended to be found in areas close to water during the mid-day periods. When temperatures exceed 35°C, water requirements for beef cattle range from 8 to 15 kg of water per kg of dry matter intake (NRC, 1981). This is substantially more than the water requirements for temperatures within the thermal neutral zone, which range from 3 to 5 kg of water per kg of dry matter intake.

As temperatures increase beyond the thermal neutral zone of 15 to 25°C, intake is depressed as well. When temperatures exceed 35°C, intake may be depressed by as much as 5 to twenty percent. However, intake may depress to a lesser extent when shade is available, such as in most riparian areas. It is not clear whether intake is lowered due to increasing temperatures alone, or due to increased water consumption, resulting in more rumen fill.

Porath et al. (2002) concluded that off stream water sources could in fact alter distribution patterns in cattle in northeastern Oregon mixed conifer-grazing systems. It is apparent by the thermally homogenous states displayed in the mid-day portions of the thermal graphs for each grazing season (Figures 3.5, 3.6, 3.7, and 3.8.) that cattle could be lured to areas with water, be they riparian or upland, in order to cool their core temperature.

Cattle may tend to favor riparian areas, despite temperatures, and the presence of water due to the diffusion of direct solar radiation in the lowland areas. Liechty (1992), Morecroft et al. (1998), and Potter et al. 2001), all agree that areas with cover are cooler than open areas. Walsberg (1992) concluded that organisms receive long-wave radiation emitted from the atmosphere, the substrate, and other surroundings such as vegetation. It is apparent that the incidence of solar radiation in riparian areas is somewhat lower than in upland areas.

The study conducted by Mendel et al. (1971) concluded that a cooling period of six hours in the evening (1600-2200) was sufficient to maintain body weight gains, compared to 12 hours of cooling in the day. Although the majority of the pasture is within the confines of the thermal neutral zone, some cattle locations are found within the coolest parts of the pasture. Both Mendel et al. (1971) and Hahn (1999) note a lag time in body temperature cooling of 3-5 hours.

Cattle often bed down at night, in the last place they eat, and start their grazing day in the same location, which is often the upland areas (Parsons et al. 2002, Morrison et al. 2003).

Implications

By understanding the diurnal thermal regimes present on a landscape, and the subsequent cattle movements associated with the thermal patterns, managers can be better prepared for times when alterations of grazing patterns may be most effective. Either through herding, or placement of offstream water and or supplementation (Porath et al. 2002) grazing distribution may be improved in order to maximize distribution. In addition, managers will possible by able to predict when cattle will not be present in riparian areas, based strictly on ambient temperatures

Thermal regimes are dynamic on a landscape level. Throughout the day, as well as the season, temperatures are constantly changing. With the changing temperatures, animal responses to the changing thermal regimes are changing as well. The better the understanding that managers have of both changing temperatures, and their effect on livestock, the more appropriate management decisions will be.

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CHAPTER 4

SUMMARY

In review of the two previous studies, it is apparent that a multitude of factors play a significant role in the distribution patterns of cattle. While each individual factor such as slope, elevation, forage production, distance to water, aspect, and temperature play important roles in distribution, it is often the combination of all factors working in unison that is ultimately driving distribution.

Temperature has been shown to vary greatly on a landscape basis; however, it is the result of the interactions of slope, aspect, elevation, wind speed, and solar radiation that cause the fluctuations in thermal regimes. An understanding of the interactions of environmental variables is crucial in development of sustainable management plans.

Each grazing situation is unique in many different ways. Some pastures are comprised of flat open areas, while others are steep and rocky. In most cases, forested rangeland pastures are a combination of many types of grazing regimes, which are constantly changing.

On a daily basis, temperature can vary greatly, altering the distribution of cattle for brief periods of time. A passing rainstorm, cloudbank, or cold front can quickly affect the physiological responses of cattle.

Precipitation, as a stand-alone entity, or in conjunction with temperature can vary the amount of available forage on a yearly, monthly and even a daily basis. Prolonged periods of high temperatures are often in conjunction with low amounts of precipitation, resulting in less available forage for the current year, and often, depending on particular climate regimes, the next years potential vegetative growth. The combination of drought and increased temperatures often causes cattle to shift their diets to what vegetation is available, be it shrubs, trees, and in some cases, sensitive riparian vegetation.

Competition, both interspecific and intraspecific can also alter grazing distribution habits. As the results from study one indicate, cattle of different ages do in fact utilized environmental variables to different extents and degrees. Be it differences in age, or experience on a pasture, or social status, older cattle tend to distribute a greater proportion of the pasture. It has still to be fully determined if pecking order, or social status among cattle directly effects distribution. Cattle of differing ages may prefer to graze with other cows they are familiar with, rather than ones they have not been previously exposed to.

Season of use is a variable that must be considered as well. Often as the grazing season progresses, the nutrient value of many plants in forested range situations decline in crude protein, thus causing shifts in diet preferences of cattle. If available, shrubs and some species of tree, such as willow and alder become a larger source of nutrients.

These forms of vegetation are often found in riparian areas in conjunction with the presence of water. The combination of the need for water and shifting of diet to shrubs and trees can be detrimental to the riparian area vegetation. Additionally, the nutrient requirements of the cattle are often not met, resulting in increased physiological stress on the cow, and her calf, if she is lactating at the time.

Each of these concepts must be regarded when devising management plans. Each situation must be assessed to the fullest extent possible, and the proper combination of management tools employed to insure sustainability. In some cases, offstream water and supplement will alter distribution to the extent to insure desired utilization. In other instances, herding of animals, or use of electric fences might best suit both the environmental and economical constraints at hand.

In other instances, it might feasible to graze pastures with a larger proportion of riparian areas with older cattle, perhaps in conjunction with off stream water.

In short, there is no one size fits all answer for sustainable range management systems; each grazing situation must be tried on to see how it fits. Some will be just right, while others require a little mending to make them fit just right.

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APPENDICES

APPENDIX A: MEAN, MINIMUM AND MAXIMUM AMBIENT AND BLACK BALL TEMPERATURES (°C). BEAR PASTURE, STARKEY EXPERIMENTAL FOREST AND RANGE

Table A.1: 2001 Early season (5 Aug-30 Aug) temperatures, Bear Pasture, Starkey Experimental Forest and Range.

Sample Date	*Mean Ambient Temp.*	*Min. Ambient Temp.*	*Max. Ambient Temp.*	*S.E.*	*Mean B.B. Temp.*	*Min. B.B. Temp.*	*Max. B.B. Temp.*	*S.E.*
5 Aug	19	18	22	0.01	19	18	24	0.04
6 Aug	22	18	40	0.05	22	18	37	0.09
7 Aug	24	7	38	0.08	24	7	45	0.16
8 Aug	22	5	34	0.10	22	4	44	0.20
9 Aug	19	4	34	0.12	21	3	44	0.24
10 Aug	22	5	42	0.13	24	4	49	0.29
11 Aug	22	8	39	0.12	24	7	49	0.29
12 Aug	21	7	39	0.12	23	7	50	0.28
13 Aug	19	10	34	0.09	21	10	44	0.23
14 Aug	21	8	36	0.11	23	8	46	0.26
15 Aug	22	9	37	0.10	25	9	47	0.26
16 Aug	21	8	37	0.11	23	7	46	0.26
17 Aug	20	7	35	0.11	23	7	45	0.26
18 Aug	16	3	30	0.10	18	3	38	0.25
19 Aug	12	-2	28	0.12	14	-2	39	0.28
20 Aug	13	0	30	0.12	16	-1	40	0.29
21 Aug	13	0	30	0.12	16	-1	39	0.28
22 Aug	15	5	28	0.08	16	5	38	0.20
23 Aug	13	5	23	0.06	14	5	29	0.14
24 Aug	11	1	26	0.09	14	0	37	0.24
25 Aug	13	0	32	0.13	15	0	43	0.30
26 Aug	17	3	36	0.13	20	3	46	0.30
27 Aug	18	4	33	0.12	21	4	44	0.28
28 Aug	16	3	32	0.11	18	2	42	0.27
29 Aug	16	3	33	0.12	19	3	43	0.28
30 Aug	17	4	34	0.12	20	3	45	0.29

Maximum and minimum temperatures are 99 percent confidence interval values.

Table A.2: 2001 Late season (31 Aug-25 Sep), Bear Pasture, Starkey Experimental Forest and Range.

Sample Date	*Mean Ambient Temp*	*Min. Ambient Temp*	*Max. Ambient Temp*	*S.E.*	*Mean B.B. Temp*	*Min B.B. Temp*	*Max B.B. Temp*	*S.E.*
31 Aug	17	6	32	0.10	19	6	42	0.24
1 Sep	16	4	30	0.10	17	4	43	0.24
2 Sep	14	1	32	0.12	16	1	41	0.28
3 Sep	16	3	32	0.11	17	3	42	0.26
4 Sep	15	3	32	0.12	17	2	42	0.28
5 Sep	11	3	25	0.07	12	2	30	0.16
6 Sep	9	-1	23	0.08	11	-2	32	0.21
7 Sep	9	-2	21	0.08	11	-2	30	0.21
8 Sep	9	-5	27	0.12	11	-5	38	0.29
9 Sep	14	-1	32	0.13	15	-2	43	0.31
10 Sep	16	1	33	0.13	17	1	43	0.29
11 Sep	16	2	33	0.12	18	1	43	0.28
12 Sep	17	5	33	0.11	19	4	43	0.28
13 Sep	16	11	25	0.05	16	11	32	0.11
14 Sep	16	5	31	0.10	17	4	41	0.25
15 Sep	16	4	29	0.10	17	3.5	38	0.22
16 Sep	15	7	26	0.07	16	7	35	0.16
17 Sep	14	3	30	0.11	16	2.0	41	0.25
18 Sep	14	1	29	0.11	15	0	38	0.28
19 Sep	10	-2	25	0.10	12	-3	34	0.23
20 Sep	11	-3	31	0.13	12	-3	41	0.30
21 Sep	12	-2	27	0.11	13	-2	35	0.25
22 Sep	13	0	32	0.12	15	0	42	0.28
23 Sep	16	2	33	0.13	17	1	42	0.28
24 Sep	18	5	33	0.11	19	5	41	0.23
25 Sep	14	4	30	0.08	14	3	31	0.15

Maximum and minimum temperatures are 99 percent confidence interval values.

Table A.3: 2002 Early season (15 Jul-8 Aug) temperatures, Bear Pasture, Starkey Experimental Forest and Range.

Sample Date	*Mean Ambient Temp.*	*Min. Ambient Temp.*	*Max. Ambient Temp.*	*S.E.*	*Mean B.B. Temp.*	*Min. B.B. Temp.*	*Max. B.B. Temp.*	*S.E.*
15 Jul	19	8	30	1.64	22	7	44	3.64
16 Jul	20	8	36	0.14	23	7	46	0.37
17 Jul	20	6	35	0.11	23	6	46	0.29
18 Jul	19	6	34	0.08	21	5	44	0.20
19 Jul	19	12	30	0.07	21	12	39	0.19
20 Jul	16	2	33	0.12	19	2	42	0.30
21 Jul	18	2	34	0.13	20	2	44	0.31
22 Jul	19	5	32	0.11	20	5	38	0.24
23 Jul	21	8	37	0.11	24	8	46	0.27
24 Jul	21	8	36	0.11	23	7	46	0.28
25 Jul	19	7	32	0.09	20	7	42	0.23
26 Jul	18	6	31	0.10	20	6	40	0.24
27 Jul	16	4	30	0.10	18	3	40	0.25
28 Jul	17	3	34	0.12	19	2	4	0.29
29 Jul	19	7	34	0.10	21	6	44	0.26
30 Jul	19	6	34	0.11	21	5	42	0.26
31 Jul	14	0	30	0.11	17	0	38	0.27
1 Aug	14	-2	34	0.15	17	-2	44	0.34
2 Aug	15	1	30	0.11	17	1	38	0.27
3 Aug	12	-4	32	0.14	15	-4	41	0.32
4 Aug	13	6	23	0.06	14	5	26	0.14
5 Aug	9	-6	23	0.10	11	-11	32	0.24
6 Aug	11	3	22	0.06	13	3	29	0.15
7 Aug	9	-7	24	0.11	12	-16	34	0.26
8 Aug	12	-2	28	0.12	14	2	39	.030

Maximum and minimum temperatures are 99 percent confidence interval values.

Table A.4: 2002 Late season (9 Aug-1 Sep) temperatures, Bear Pasture, Starkey Experimental Forest and Range

Sample Date	*Mean Ambient Temp.*	*Min. Ambient Temp.*	*Max. Ambient Temp.*	*S.E.*	*Mean B.B. Temp.*	*Min. B.B. Temp*	*Max. B.B. Temp.*	*S.E.*
9 Aug	15	0	34	0.14	18	4	34	0.33
10 Aug	18	4	35	0.13	20	3	44	0.30
11 Aug	17	2	32	0.11	19	2	41	0.27
12 Aug	16	2	33	0.12	18	2	42	0.29
13 Aug	18	3	37	0.13	20	3	46	0.31
14 Aug	20	4	38	0.13	22	4	46	0.30
15 Aug	20	5	36	0.12	22	4	44	0.28
16 Aug	17	4	32	0.11	19	3	40	0.25
17 Aug	15	-2	34	0.15	17	-2	42	0.33
18 Aug	16	0	32	0.12	18	0	40	0.28
19 Aug	15	-2	32	0.12	17	2	40	0.27
20 Aug	13	1	25	0.09	15	1	32	0.21
21 Aug	9	3	19	0.05	8	3	22	0.11
22 Aug	11	0	26	0.10	13	0	34	0.23
23 Aug	13	2	26	0.09	15	2	36	0.23
24 Aug	14	2	28	0.10	16	2	36	0.23
25 Aug	15	3	30	0.10	16	3	39	0.24
26 Aug	14	8	25	0.06	15	8	34	0.16
27 Aug	14	4	28	0.09	16	4	37	0.23
28 Aug	16	5	32	0.10	18	4	41	0.26
29 Aug	16	6	30	0.09	17	5	40	0.21
30 Aug	15	5	30	0.09	17	5	39	0.23
31 Aug	14	2	30	0.12	17	1	40	0.28
1 Sep	16	5	28	0.09	17	4	34	0.21

Maximum and minimum temperatures are 99 percent confidence interval values

APPENDIX B: INFLUENCE OF THERMAL ENVIRONMENT ON PHYSIOLOGICAL RESPONSES OF BEEF CATTLE

Table B.1: Intake value responses to temperature (Effect of Environment on Nutrient Requirements of Domestic Animals, NRC 1981)

Thermal Environment	*Intakes Relative to Values Tabulated in Nutrient Requirements of Beef Cattle*
> 35°C	Marked depression in intake, especially with high humidity and/or solar radiation and where there is little night cooling. Cattle on full feed- 10 to 35 percent depression. Cattle near maintenance- 5 to 20 percent depression. Intakes depressed less when shade or cooling available and with low fiber diets.
25 to 35 °C	Intake depressed 3 to 10 percent.
15 to 25°C	Preferred values as tabulated in Nutrient Requirements of Beef Cattle.
5 to 15°C	Intake stimulated 2 to 5 percent.
-5 to 5°C	Intake may be stimulated 3 to 8 percent. Sudden cold snap or storm may result in digestive disturbances in young stock.
-15 to –5°C	Intake stimulated 5 to 10 percent.
<-15°C	Intake stimulated 8 to 25 percent. Intakes during extreme cold (> -25°C) or during blizzards and storms may be temporarily depressed. Intake of high roughage feeds may be limited by bulk.

Table B.2: Water Requirements of Beef Cattle in Different Thermal Environments (Effect of Environment on Nutrient Requirements of Domestic Animals, NRC 1981)

Thermal Environment	*Water Requirements*
> 35°C	8 to 15 kg water per kg DM intake.
25 to 35 °C	4 to 10 kg water per kg DM intake.
15 to 25°C	3 to 5 kg water per kg DM intake. Young and lactating animals require10-50 percent more water.
5 to 15°C	2 to 4 kg water per kg DM intake.
<–5°C	2 to 3 kg water per kg DM intake. Increases of 50-100 percent occur with a reise in ambient temperature following a period of very cold temperature, e.g., a rise from –20 to 0°C.

APPENDIX C: KOOLTRAK© DATA LOGGER, AMBIENT AND BLACK BALL THERMAL PROBES

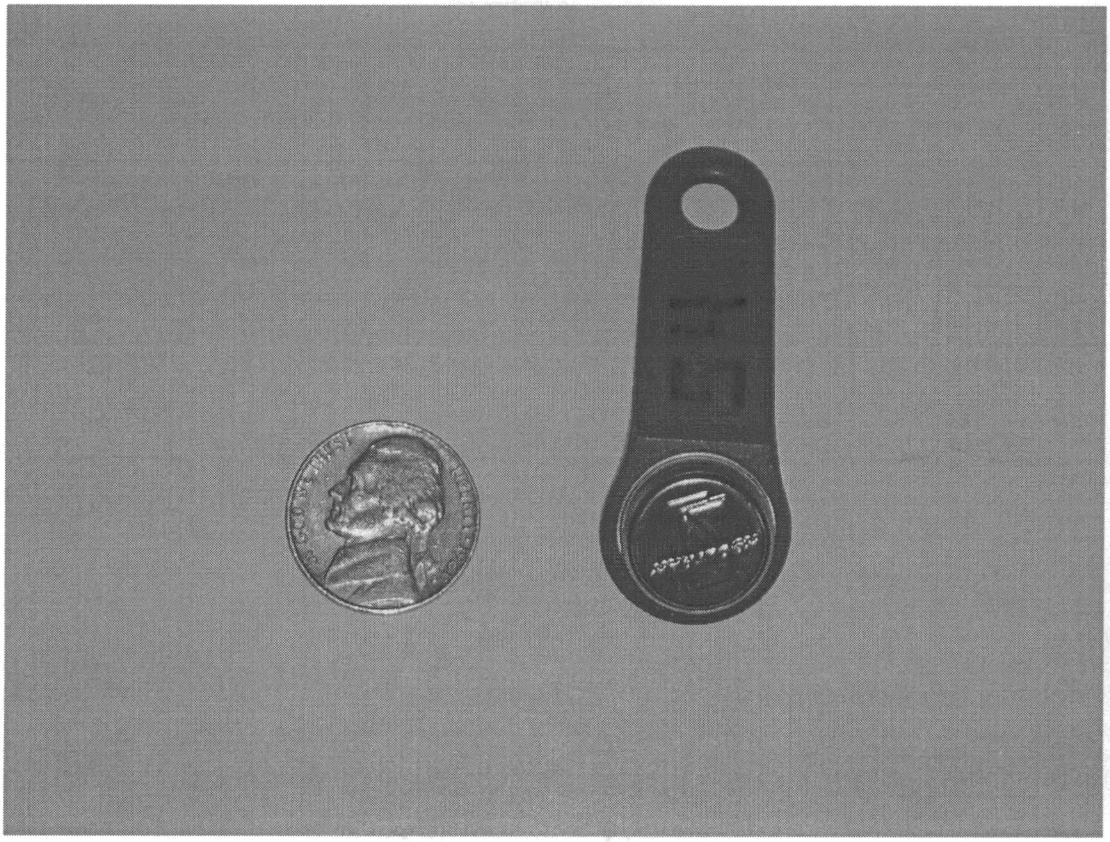

Figure C.1: Size comparison of Kooltrak© data logger and angled fob mounting device to a nickel. Actual data logger is the metallic portion of the blue fob on the right side of image.

Figure C.2: Ambient only thermal probe station, approximately 1 m above ground level. Data logger is suspended within the cap portion of the station. Thermal probe station was perforated to allow free air passage.

Figure C.3: Black Ball and ambient thermal probe station, approximately 1 m above ground level. Data logger is suspended within black ball and ambient portion of the probe. Probe stationed was perforated to allow free air passage.