Winter range use by cattle : microclimate and diet selection
by John Michael Beaver

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Range Science
Montana State University

Abstract:
In northern climates, winter conditions can cause animals to lose weight and body condition. Our first objective was to compare winter range use by young cattle, inexperienced with winter range, with old cattle experienced with winter range. Our second objective was to determine if simple micrometeorological measurements could accurately model standard operative temperature (Tes) in mule deer and cattle in winter. Our final objective was to determine if cattle select higher quality diets than that present in two dormant native bunchgrasses.

With Objective One, we alternated 3 year old cows weekly with 7-8 year old cows on the same 150 ha pasture for approximately two months over two winters. We measured standing crop at different locations within the pasture, and at cattle locations. We calculated standard operative temperature (Tes) based on ambient and blackglobe temperatures and windspeed, and cattle resistance to heat loss. We calculated Tes at group locations, and at 12 locations in the pasture to assess available thermal environments.

Three year old cattle used unprotected areas more often than 7-8 year old cattle. Three year old cattle were in areas where Tes were below their lower critical temperature more often than 7-8 year old cattle. Three year old cattle did not graze in areas with higher standing crop than what was initially available although 7-8 year old cattle did. Microclimates were more important than forage in predicting 7-8 year old cattle use of the pasture.

For Objective Two, we calculated Tes for mule deer and cattle in winter. We regressed Tes with blackglobe and ambient temperature, and windspeed. We applied our mule deer regression model to an independent data set with different weather conditions. Our mule deer and cattle regression models represented Tes well for both species (adj. R2 = .96 and .97, respectively). Our mule deer regression model also matched the independent data set well.

For Objective Three, we randomly located and clipped three plants of Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) at 12 transects within a 324 ha pasture. We clipped three times during the 1993-94 winter, and once during the 1994-95 winter due to low variability in the first winter. We also evacuated the rumens of six cattle three times during the winter, allowed them to graze for 45 min to 1 h, and collected rumen samples. There was less green material in the rumen samples than in the clipped samples on all but one occasion indicating that during these two winters, cattle were unable to select a higher quality diet than that available.

Winter range in northern climates challenges an animal's ability to maintain homeostasis, and obtain adequate nutrition. Seven-eight year old cattle are apparently more adept at avoiding cold extremes than are 3 year old cattle. When there is little green material available both age groups are probably unable to select higher quality diets than that usually available during winter.

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APPROVAL

of a thesis submitted by

John Michael Beaver

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

6 July 1995 | [signature]
Date | Chairperson, Graduate Committee

Approved for the Major Department

July 10, 1995 | [signature]
Date | Head, Major Department

Approved for the College of Graduate Studies

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Date 7-8-95

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ABSTRACT

In northern climates, winter conditions can cause animals to lose weight and body condition. Our first objective was to compare winter range use by young cattle, inexperienced with winter range, with old cattle experienced with winter range. Our second objective was to determine if simple micrometeorological measurements could accurately model standard operative temperature (T_{es}) in mule deer and cattle in winter. Our final objective was to determine if cattle select higher quality diets than that present in two dormant native bunchgrasses.

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Three year old cattle used unprotected areas more often than 7-8 year old cattle. Three year old cattle were in areas where T_{es} were below their lower critical temperature more often than 7-8 year old cattle. Three year old cattle did not graze in areas with higher standing crop than what was initially available although 7-8 year old cattle did. Microclimates were more important than forage in predicting 7-8 year old cattle use of the pasture.

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For Objective Three, we randomly located and clipped three plants of Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) at 12 transects within a 324 ha pasture. We clipped three times during the 1993-94 winter, and once during the 1994-95 winter due to low variability in the first winter. We also evacuated the rumens of six cattle three times during the winter, allowed them to graze for 45 min to 1 h, and collected rumen samples. There was less green material in the rumen samples than in the clipped samples on all but one occasion indicating that during these two winters, cattle were unable to select a higher quality diet than that available.

Winter range in northern climates challenges an animal's ability to maintain homeostasis, and obtain adequate nutrition. Seven-eight year old cattle are apparently more adept at avoiding cold extremes than are 3 year old cattle. When there is little green material available both age groups are probably unable to select higher quality diets than that usually available during winter.

CHAPTER 1

INTRODUCTION

In northern climates, thermal conditions and low forage nutritional quality can increase weight loss in animals and decrease reproductive performance. In winter animals often decrease their exposure to wind or increase their exposure to long and short wave radiation (Senft and Rittenhouse, 1985; Schwab and Pitt, 1991; Sakurai and Dohi, 1992). This is important where environmental conditions may be below the animal's thermoneutral zone. However, animals must balance this thermoregulatory behavior so that it does not conflict with other behaviors such as obtaining food (Ingram and Dauncy, 1985). Presumably, animals thermoregulate by alternating behaviors that require energy with those that conserve energy. The thermal and forage characteristics of an area may influence how often, and in what way an animal uses that area.

The ability to match behaviors to thermal and forage resources may be learned or innate. Several studies show that young, inexperienced animals improve their foraging skills and social abilities by associating with older, experienced animals (Provenza and Balph, 1987; Thorhallsdottir et al., 1990; Green, 1992; Olson et al., 1992). Habitat selection may also be learned (Hunter and Milner, 1963; Wecker, 1963). In Chapter 2, we compared winter range use by 7-8 year old cattle experienced with winter range, with 3 year old cattle inexperienced with winter range.

The thermal environment which an animal experiences is not accurately described by ambient temperature or some other weather measurement alone. Operative temperature and the related standard operative temperature are often used as biophysical indices of an animal's thermal environment (Bakken, 1980; Parker and Robbins, 1984; Vispo and Bakken, 1993). Operative and standard operative temperature incorporate variables such as ambient temperature, windspeed, and short and long-wave radiation with species specific variables such as resistance to heat flow. Thus they more accurately represent the thermal environment that an animal experiences.

Measuring standard operative temperature in the field can be difficult. Measurements usually require expensive equipment which is not easily mobile, or life-like copper mounts of animals (Crawford et al., 1983; Bakken et al., 1985; Bakken, 1992). Standard operative temperature would be more useful to ecologists and biologists if mathematical models could relate it to more easily obtained microclimate measurements. In Chapter 3, we determined if regression equations could incorporate simple micrometeorological data to model standard operative temperature for two large endotherms, mule deer and cattle.

In addition to stressful thermal environments, animals can be stressed by poor forage quality in winter. Cattle diet selection in winter is inhibited by overall poor forage quality (Stuth, 1990). The amount of green material in a forage sample should be an index of its nutritional quality. Green herbage of Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Agropyron spicatum*) is higher quality forage at all times of the year than dead forage (Houseal and Olson, accepted). Thus, cattle diet selection can be estimated by comparing the amount of green forage in rumen samples with that available in the pasture or landscape (Launchbaugh et al., 1990). In Chapter 4, we determined if cattle select diets of higher quality than is generally available on native winter range by comparing the amount of green material in rumen samples with randomly clipped native bunchgrasses.

CHAPTER 2

WINTER RANGE USE BY DIFFERENT AGED CATTLE IN SOUTHWESTERN MONTANA

Introduction

In northern climates, winter conditions can severely stress animals. Because cold stress requires an animal to raise its regulatory heat production to maintain a constant body temperature (Christopherson, 1985), there is less energy available for growth and feeding efficiency (Webster et al., 1970). Cattle and other endotherms use a variety of physiological and behavioral mechanisms to avoid cold stress (Parker and Robbins, 1985). In winter animals often decrease their exposure to wind or increase their exposure to long and short wave radiation (Senft and Rittenhouse, 1985; Schwab and Pitt, 1991; Sakurai and Dohi, 1992). This is important in an environment where ambient conditions may be below the animal's thermoneutral zone.

Animals are capable of seeking out microclimates to reduce their exposure. However, they must balance this behavior so that it does not conflict with other behaviors such as obtaining food (Ingram and Dauncy, 1985). Presumably, animals thermoregulate by alternating behaviors that require energy with those that conserve energy. In a landscape that consists of a range of available microclimates and forage resources, animals may be able to graze, an energetically expensive activity (Osuji, 1974; Malechek and Smith, 1976), in moderate microclimates. Thus, thermal environments and forage resources such as standing crop and nutritional quality interact to determine an animal's location.

The ability to balance grazing and resting behavior with thermal and forage resources may be learned or innate. Several studies show that young, inexperienced animals improve their foraging skills and social abilities by associating with older, experienced animals (Provenza and Balph, 1987; Thorhallsdottir et al., 1990; Green, 1992; Olson et al., 1992). Habitat selection may also be learned (Hunter and Milner, 1963; Wecker, 1963). Learning to use resources efficiently may lessen weight loss or loss of condition of animals in winter. The objective of our study was to determine if older cattle, experienced with winter grazing use winter range resources differently than younger cattle, inexperienced with winter grazing.

Methods

Study Site and Animals

The study site is a 150 hectare pasture on the Montana Agricultural Experiment Station Red Bluff Research Ranch (latitude 45° 35'N, longitude 111° 39'W) near Norris, Montana. The pasture has sandy and silty range sites common to southwestern Montana. Topography is varied with three large draws, and several smaller draws within the pasture. Slopes are predominately southwest facing, and usually snowfree because of persistent winds and high solar radiation during most of the winter. Elevations range from approximately 1520 - 1770 m. Three small springs provide water. The dominant habitat type is *Festuca idahoensis/Agropyron spicatum* with a *Rhus trilobata/Festuca idahoensis* habitat type occurring on the southwest slopes of major draws (Mueggler and Stewart, 1980). Rocky Mountain juniper (*Juniperus scopulorum)* and limber pine (*Pinus flexilis)* are scattered on the slopes throughout the pasture, and chokecherry (*Prunus virginianus)* occurs along the springs in the bottoms of draws. Along with topographical variation, this larger vegetation provides a range of microclimates. Each year prior to our study, the pasture was lightly grazed in late fall by cattle. This reduced standing crop slightly around water, salt, and supplement areas.

We alternated two groups of Angus x Hereford cattle, one experienced with winter range (7-8 year olds), and one inexperienced with winter range (3 year olds) every other week on the pasture. During Winter 1 (29 Dec. 1993 to 4 Feb. 1994), there were ten cattle per group. During Winter 2 (18 Dec. 1994 to 17 Feb. 1995), ten cattle were in the 7-8 year old group and nine were in the 3 year old group. In Winter 1, we observed each group for three weeks. In Winter 2, we extended the observation period to four weeks per group to encompass a wider variety of weather extremes.

During both winters we recorded grazing, resting, and traveling time (min) for the majority of each group from 0800 to 1600 h. In Winter 2, we individually weighed and measured backfat on all cattle immediately before and after the study. The mean initial weight and backfat of 7-8 year old cattle was 625±19.5 kg (SE) and .38±.08 cm (SE) respectively. The mean initial weight and backfat of 3 year old cattle was 544±15.5 kg (SE) and .52±.10 cm (SE) respectively. We compared weight and backfat loss between the two groups using initial body weight and backfat as covariates. In a small herd animal behavior is not necessarily independent. Therefore, changes in weight and backfat should be considered subsamples and not replicates. Thus, these results cannot be inferred to other cattle grazing winter pasture (Wester, 1992).

The cattle were not supplemented or fed during the observation period of either winter. During Winter 1, only cattle in the 7-8 year old group were pregnant. During Winter 2, both groups of cattle were pregnant. When a group was not on the study pasture, it was in an adjoining pasture of similar vegetation and soils, although the topography was less varied. Interaction between the two groups was infrequent and short.

Environmental Measurements

To assess how 7-8 year old and 3 year old cattle use certain microclimates relative to the range of microclimates available, we established 3 transects of increasing elevation on the pasture with four weather stations per transect. Four landscape positions were represented by the twelve stations. Three were along an exposed ridge, three were at midslope of the ridge, three were at locations within a draw, and three were along an open bench. We measured blackglobe (T_g) and ambient temperatures (T_a), and windspeed (m s^{-1}) at backbone height to a cow (1.3 m, Yousef, 1989) at each cattle groups' location. We clipped three .25 m^2 frames to determine standing crop in the immediate vicinity of each group. We recorded whether the majority of the group was grazing or resting. We also visually classified the majority of the groups' location as unprotected, moderately protected, or protected from wind exposure by large vegetation or topography. We then immediately measured the same weather variables at the twelve weather stations to compare weather conditions at the group location with conditions available in the pasture. Total time between all measurements was 30 to 40 min. We recorded the above measurements at 0800, 1200, and 1600 hr on days 1, 3, and 5 of each week (n=27 Winter 1, n=36 Winter 2).

Our blackglobe thermometer was a 10.2 cm copper sphere painted matte black (Bond and Kelly, 1955) that has a short and long wave absorptivity similar to most animal and natural surfaces (.89 and .95 respectively; Campbell, 1977; Walsberg, 1992). A mercury thermometer was inserted through a rubber stopper into the center of the globe. The ambient thermometer consisted of a mercury thermometer surrounded by an aluminum shield to shade the thermally sensitive end. We averaged windspeeds over ten seconds at the cattle locations and weather stations with a hand held digital anemometer.

Before turning cattle onto the pasture, we clipped .25 m^2 frames in protected, moderately protected, and unprotected areas of the pasture. We sampled enough plots per area to be within 20% of the mean with 90% confidence (n=90 Winter 1; n=71 Winter 2). In Winter 1, plots were interspersed across the pasture within protections classes (Hurlbert, 1984). In Winter 2, plots were randomly chosen within protection classes. We used planned linear contrasts to determine if standing crop in protection classes selected by cattle was different from what was available in the protection classes. In the same manner we compared standing crop among protection classes selected by cattle. *P*-values < 0.10 are discussed. Since we considered the pasture the experimental unit this study is not replicated. Thus we did not make statistical comparisons between winters to avoid temporal pseudoreplication (Hurlbert, 1984).

Forage sampled before our study cattle used the pasture, and that sampled at cattle locations during the study, were dried in a forced air oven at 37°C for 5 to 7 days and weighed. In Winter 2, we composited samples taken at cattle locations by collection time and day, ground them through a 1 mm Wiley mill, and analyzed them for crude protein (*CP*), acid detergent fiber (*ADF*), and neutral detergent fiber (*NDF*). Forage data are expressed on a dry matter basis.

Thermal Index

Although ambient temperature has often been used to represent the thermal environment experienced by an animal, it does not incorporate all of the components that characterize the thermal environment that an animal experiences. Standard operative temperature, T_{es} (Bakken, 1980; 1981) is a more appropriate biophysical index because it incorporates the animal's resistance to heat loss, its body temperature, long and short wave radiation, and windspeed. Standard operative temperature and operative temperature T_e, (Winslow et al., 1937; Campbell, 1977) have often been used to express the thermal environment experienced by large endotherms (Parker and Gillingham, 1990; Merrill, 1991; Schwab and Pitt, 1991; Demarchi and Bunnell, 1993). Standard operative temperature is expressed as:

$$T_{es} = T_b - [(r_{bs} + r_{es})/(r_b + r_e)] \cdot (T_b - T_e) \qquad (1)$$

where T_b is body temperature (°C), r_b is the thermal resistance of skin and insulation (s m^{-1}), r_e is the thermal resistance between outer surface and environment (s m^{-1}), and r_{bs} and r_{es} are the values of r_b and r_e in the standard environment with windspeed < 1 m s^{-1} (Bakken, 1981).

To calculate T_{es} generally requires either sophisticated equipment such as a pyranometer and a net radiometer, or a realistic copper model of the animal being measured (Merrill, 1991; Walsberg, 1992; Bakken, 1992). Because this equipment is difficult to transport, and because we did not have a copper model of a cow, we developed a mathematical relationship between T_{es}, and windspeed, and blackglobe and ambient temperature (adjusted r^2 = .94). We substituted this equation for T_{es} (Chapter 3). We used T_b for beef cattle of 38.6°C (Christopherson et al., 1979), and resistance ratios appropriate for cattle as estimated by Webster (1970). We estimated T_{es} at the group location and compared that with mean T_{es} estimated at the exposed ridge weather stations, and with mean T_{es} estimated at the protected draw weather stations. We also compared the T_{es} estimated at the above locations with the assumed lower critical temperatures (*LCT*) of -23°C for pregnant cattle, and -13°C for the non-pregnant cattle in Winter 1 (Webster, 1970). In Winter 2, both groups were composed of pregnant animals, and thus their *LCT* was assumed to be -23°C. An animal's *LCT* is the temperature at which it must raise its regulatory heat production to maintain a constant body temperature. Comparing T_{es} at animal and transect locations to the *LCT* is an indirect measure of actual or possible cold stress in various environments.

GIS and Logistic Regression Analysis

Thermal and forage resources are distributed unevenly across the pasture. Therefore we created a geographic information system GIS (Arc/Info, 1992) overlay of topography and larger vegetation, such as trees and shrubs, to map areas which were protected, moderately protected, and unprotected from wind. Arc/Info classified the percentage of the pasture in each category. We then compared the relative abundance of protection classes to their relative use by each group.

We used wind direction as the main determinate to distinguish between protection classes. The prevailing wind direction in the pasture is from 160° to 230°, therefore, we programmed the model to label areas with aspects between 340° and 50° in a draw with large vegetation as "protected". "Moderately protected" areas were defined as areas either with large vegetation outside of a draw, or in a draw without large vegetation between aspects 340° and 50°. We defined "unprotected" areas as the remaining pasture. We used Ivlev's electivity index (Ivlev, 1961; Yeo et al., 1993) to determine if cattle were in protection classes more or less than the relative abundance of those classes. The index is expressed as:

$$EI = (\text{Observed} - \text{Available}) / (\text{Observed} + \text{Available}) \qquad (2)$$

where EI = electivity index, Observed = the observations in a particular protection class, and Available = the percent of the pasture within a particular protection class. Positive numbers from 0 to 1 express preference, and negative numbers from 0 to -1 express avoidance. The closer the number is to 1 or -1, the stronger the preference or avoidance, respectively.

We used stepwise logistic regression with protection class as the dependent variable within experience group to determine which weather and forage features influenced the probability of cattle selection of microsites (SAS, 1988). We included T_{es} at cattle and weather stations, and slope, aspect, forage quantity (kg ha^{-1}), and quality (*CP, ADF, NDF*) the second year, at cattle locations as independent variables. Variables which were not significant in the model are not discussed. By incorporating variables at the cattle and weather station locations we could determine how cattle select microclimates relative to prevailing forage and microclimate resources. We used the log likelihood ratio to determine if the model was significant, and the Wald chi-square statistic with it associated *P*-value as indicators of the relative significance of independent variables (Trexler and Travis, 1993). They recommend using logistic regression for regression analysis of categorical data.

Results

Animals

In Winter 1, 7-8 year old cattle traveled less per day than 3 year old cattle although total minutes grazing and resting were similar (22 min/day vs. 76 min/day). During the morning, noon, and afternoon weather measurements, 7-8 year old cattle rested more often in either protected or moderately protected sites, and grazed more often in unprotected sites. Three year old cattle use patterns were generally similar to 7-8 year old cattle use patterns (Table 1).

In Winter 2, 7-8 year old and 3 year old cattle spent similar amounts of time grazing, resting, and traveling. As in Winter 1, 3 year old cattle use patterns were generally similar to 7-8 year old cattle use patterns (Table 1).

Table 1. Percent time grazing (G) and resting (R) in protected (P), moderately protected (MP), and unprotected (UP) areas by 7-8 year old and 3 year old cattle in Winter 1 and Winter 2.

		P		MP		UP	
		7-8 yr	3 yr	7-8 yr	3 yr	7-8 yr	3 yr
Winter 1	G	0	0	40	0	82	65
	R	100	100	60	100	18	35
Winter 2	G	40	50	50	63	65	50
	R	60	50	50	37	35	50

In Winter 2, 7-8 year old cattle lost 36±3.4 kg (SE), and .11±.07 cm (SE) of backfat. Three year old cattle lost 56.8±5.0 kg (SE), and .30±.11 cm (SE) of backfat. Seven-eight year old cattle lost less backfat (P=0.06) and weight (P=0.0003) than 3 year old cattle.

Environmental Measurements

In Winter 1, forage standing crop was lower in protected areas than it was in unprotected areas selected by 7-8 year old cattle (P=0.08). There was no relationship between forage standing crop and the selection of different protection classes by 3 year old cattle (Fig. 1a).

In Winter 2, standing crop was lower in protected (P=0.002) and moderately protected (P=0.02) areas selected by 7-8 year old cattle compared with unprotected areas selected by 7-8 year old cattle. Standing crop in unprotected areas selected by 7-8 year old cattle was also greater than that sampled in unprotected areas before the cattle entered the pasture (P=0.001). There was no relationship between forage standing crop and the selection of different protection classes by 3 year old cattle (Fig. 1b). Crude protein, *NDF*, and *ADF* were similar among sites in the different protection classes (P>0.10; Table 2).

Figure 1. Mean standing crop available in the pasture, and at 7-8 year old and 3 year old cattle locations within protected (P), moderately protected (MP), and unprotected (UP) areas during Winter 1 and 2. Error bars are standard errors.

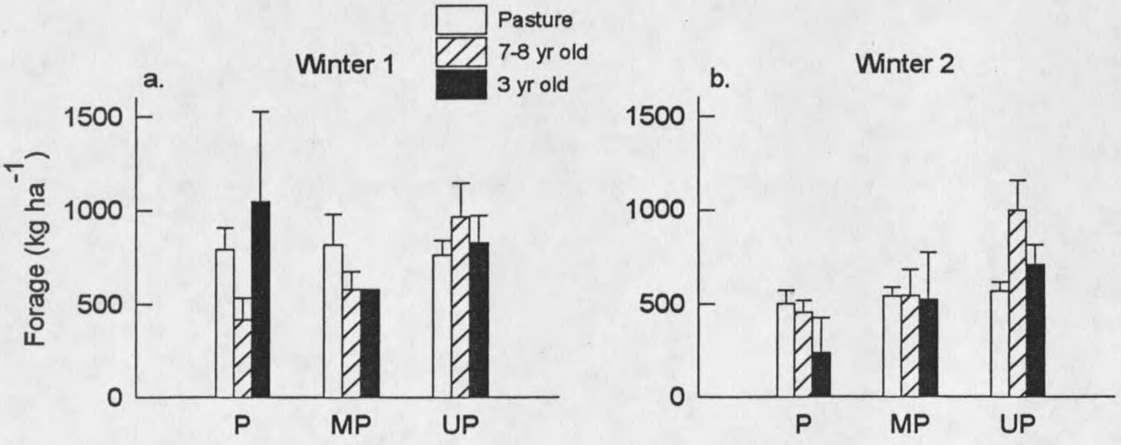
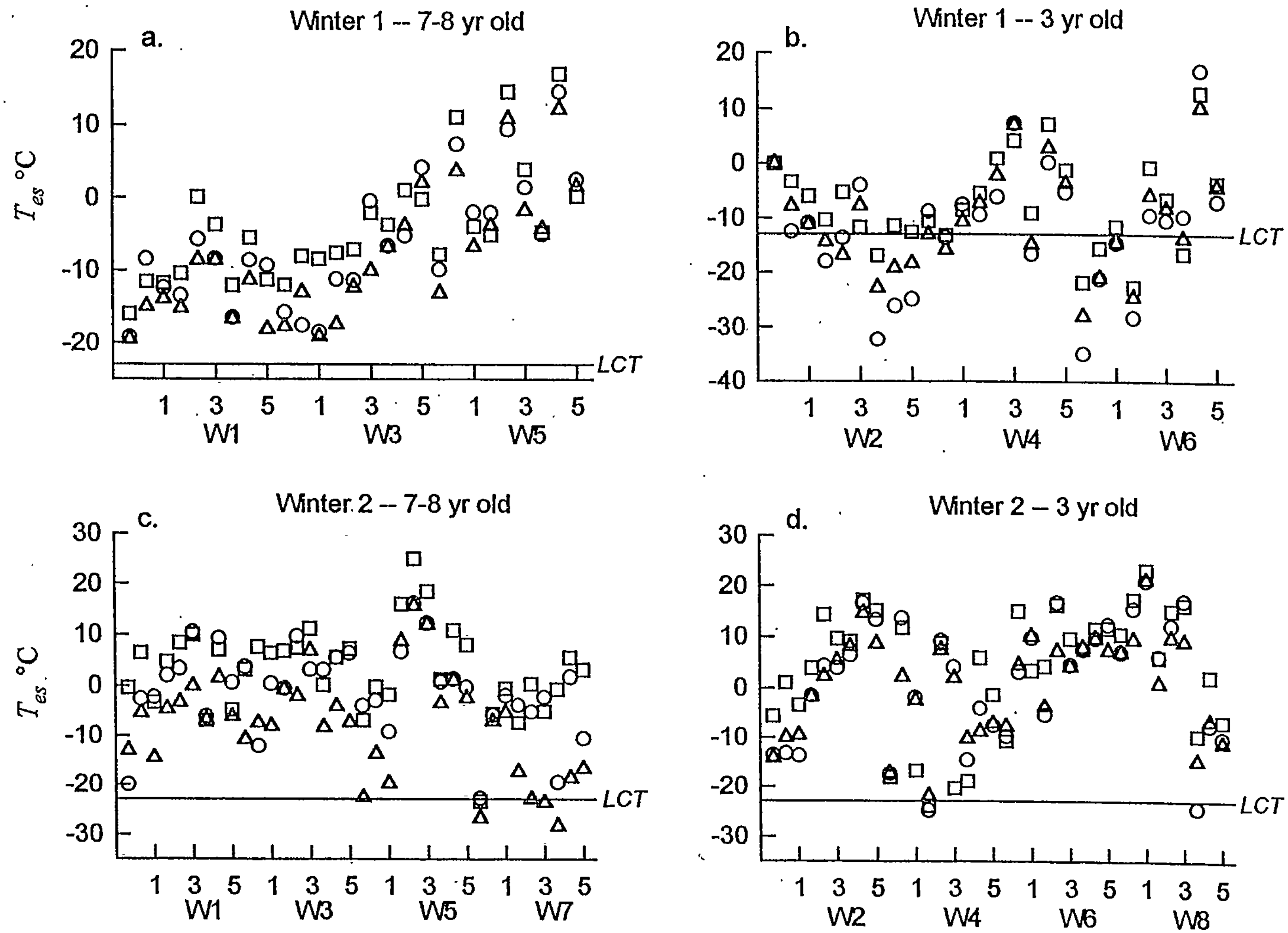


Table 2. Mean crude protein (*CP*), neutral detergent fiber (*NDF*), and acid detergent fiber (*ADF*), in protected (P), moderately protected (MP), unprotected (UP), and grazing (G) and resting (R) areas selected by 7-8 year old and 3 year old cattle in Winter 2. Standard errors are noted in parentheses.

		P	MP	UP
7-8 yr old	*CP*	5.28 (.74)	5.66 (.36)	4.75 (.16)
	NDF	74.59 (.65)	73.96 (.88)	75.19 (.82)
	ADF	42.46 (.58)	42.64 (1.0)	44.24 (.66)
3 yr old	*CP*	5.12 (1.1)	5.23 (.61)	5.25 (.18)
	NDF	73.82 (.14)	74.79 (1.0)	74.40 (.71)
	ADF	43.00 (1.0)	42.60 (.81)	42.91 (.57)

Weather was variable over both winters. In Winter 1, the mean T_{es} estimated from the ridge transects, the coldest points in the pasture, was -10.49±2.53 °C (SE) when 7-8 year old cattle were observed, and -16.11±2.96 °C (SE) when 3 year old cattle were observed. In Winter 2, mean T_{es} estimated from the ridge transects was -20.42±2.86 °C (SE) when 7-8 year old cattle were observed, and -6.63±2.85 °C (SE) when 3 year old cattle were observed. In Winter 1, 93% of T_{es} at 7-8 year old cattle locations were at or above the coldest T_{es} measured in the pasture. Three T_{es} at 7-8 year old locations were below the *LCT* of -23 °C (Fig. 2a). In contrast, 54% of T_{es} at 3 year old cattle locations were above the coldest T_{es} measured in the pasture. Several T_{es} at 3 year old cattle and transect locations were below the *LCT* of -13 °C (Fig. 2b).

Figure 2. Standard operative temperatures (T_{es}) at cattle = ○, draw = □, and ridge = △ locations within the pasture for Winter 1 (a, b) and 2 (c, d). Days per week (W) are noted on the x-axis. For each day, microclimates were measured at 0800, 1200 and 1600 h and are depicted on figures. Note that the scale of the y-axis differs in Winter 1.



In Winter 2, 89% of T_{es} at 7-8 year old cattle locations were at or above the coldest T_{es} measured in the pasture. Several T_{es} at transects were below the *LCT*, although T_{es} at 7-8 year old cattle locations were never below the *LCT* (Fig 2c). Unlike Winter 1, 75% of T_{es} at 3 year old cattle locations were above the coldest T_{es} measured in the pasture. Standard operative temperatures at transect locations were never below the *LCT* of -23 °C. However, two T_{es} at 3 year old cattle locations were below -23 °C (Fig. 2d).

GIS and Logistic Regression Analysis

Seven-eight year old and 3 year old cattle used most parts of the pasture over both winters (Fig. 3). In Winter 1, both groups tended to prefer the protected areas in the pasture (Table 3). Seven-eight year old cattle preferred the moderately protected and avoided the unprotected areas. Three year old cattle avoided the moderately protected areas and used the unprotected area in proportion to its availability. In Winter 2, 7-8 year old cattle preferred protected and moderately protected areas and avoided the unprotected areas. Three year old cattle avoided protected areas, and used moderately and unprotected areas in proportion to their availability (Table 3).

In Winter 1, standing crop, and T_{es} at cattle and ridge locations predicted 7-8 year old cattle use of the three protection classes (Table 4). Standard operative temperature at cattle and draw locations predicted 3 year old cattle use of the three protection classes (Table 4). However, since 3 year old cattle were in unprotected areas 80% of the time, the model predicted 3 year old cattle in unprotected areas all but once.

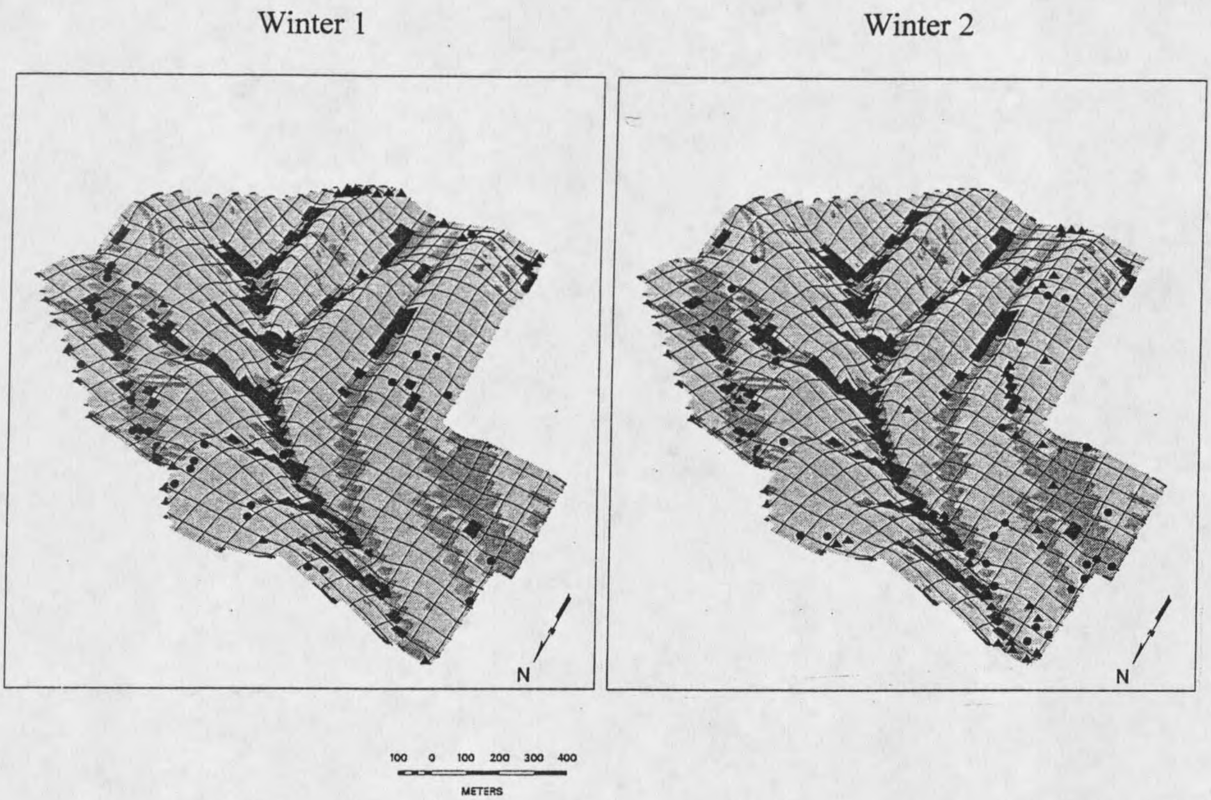


Figure 3. Seven-eight year old (●) and 3 year old (▲) cattle locations in Winter 1 and 2. Protection classes range from dark to light with protected areas the darkest, moderately protected areas lighter, and unprotected areas lightest.

In Winter 2, T_{es} at cattle, ridge, and draw locations predicted 7-8 year old cattle use of the three protection classes. Standard operative temperature and standing crop did not predict 3 year old cattle use of the three protection classes (Table 4).