



Winter range resources : forage quality and cattle selection of microclimates  
by Gregory Alan Houseal

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

Low forage quality and extreme cold and wind can stress cattle grazing northern latitude winter range. These conditions may contribute to loss of weight, body condition, and reproductive potential. The effects of low forage quality may be minimized if an adequate amount of high quality fall growth is present on range land. Diverse topography may provide natural shelter allowing cattle to maintain grazing time and forage intake in moderate microclimates when general weather conditions are extreme.

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The study site was the Montana Agricultural Experiment Station Red Bluff Research Ranch (latitude 45°35'N, longitude 111°39'W) near Norris, Montana. Forage quality was assessed by determining crude protein (CP), acid detergent insoluble nitrogen (ADIN), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents of live and dead components of bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Scribn and Smith) and Idaho fescue (*Festuca idahoensis* (Elmer) sampled bi-monthly from October 1991 to April 1993. In addition, dry matter (DM) rate and extent of disappearance and CP extent of disappearance were determined in-situ using four mature ruminally cannulated beef cows.

Microclimates were quantified by measuring ambient temperature ( $T_a$ ), black globe temperature ( $T$ ), and wind speed ( $\mu$ ) at 12 fixed points placed along topographic gradients and at the concurrent location of pregnant range cattle grazing the pasture. Cow location was classified as protected (draw), moderately protected (lower slopes), and exposed (bench, upper slopes and ridgetops) relative to topography, prevailing wind direction, and reference climate.

Bluebunch wheatgrass and Idaho fescue were similar in chemical composition within forage type throughout the year. There were differences between species and stage of maturity ( $P < 0.05$ ) in disappearance rates and extents. Fall growth was nearly equal in quality and digestibility to April growth, and maintained this quality throughout winter. Standing dead material was below NRC CP requirements (6 to 8%) year-round.

Cattle selected moderate microclimates for grazing and resting to avoid • high winds and cold temperatures. They tended to remain in microclimates above the assumed lower critical temperature (LCT) of  $-23^{\circ}\text{C}$ , even though reference conditions often were below LCT. The availability of moderate microclimates may allow cows to continue grazing, thus maintaining forage intake, even when general conditions might otherwise cause them to defer grazing.

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Bozeman, Montana.

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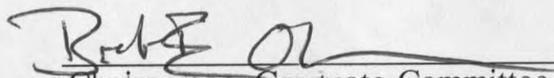
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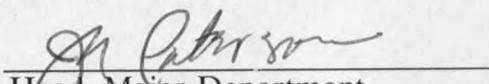
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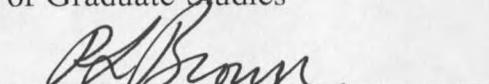
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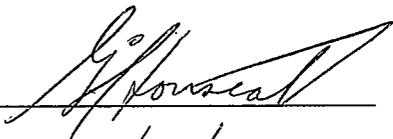
  
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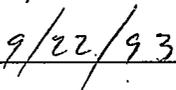
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## ABSTRACT

Low forage quality and extreme cold and wind can stress cattle grazing northern latitude winter range. These conditions may contribute to loss of weight, body condition, and reproductive potential. The effects of low forage quality may be minimized if an adequate amount of high quality fall growth is present on range land. Diverse topography may provide natural shelter allowing cattle to maintain grazing time and forage intake in moderate microclimates when general weather conditions are extreme.

Our first objective was to assess the potential of the forage quality of live and dead components of two co-dominant cool-season bunchgrasses to meet the nutritional requirements of cattle throughout the year. Our second objective was to determine if cattle select moderate microclimates while foraging to minimize cold stress when environmental conditions are severe.

The study site was the Montana Agricultural Experiment Station Red Bluff Research Ranch (latitude 45°35'N, longitude 111°39'W) near Norris, Montana. Forage quality was assessed by determining crude protein (CP), acid detergent insoluble nitrogen (ADIN), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents of live and dead components of bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Scribn and Smith) and Idaho fescue (*Festuca idahoensis* (Elmer) sampled bi-monthly from October 1991 to April 1993. In addition, dry matter (DM) rate and extent of disappearance and CP extent of disappearance were determined in-situ using four mature ruminally cannulated beef cows.

Microclimates were quantified by measuring ambient temperature ( $T_a$ ), black globe temperature ( $T_g$ ), and wind speed ( $\mu$ ) at 12 fixed points placed along topographic gradients and at the concurrent location of pregnant range cattle grazing the pasture. Cow location was classified as protected (draw), moderately protected (lower slopes), and exposed (bench, upper slopes and ridgetops) relative to topography, prevailing wind direction, and reference climate.

Bluebunch wheatgrass and Idaho fescue were similar in chemical composition within forage type throughout the year. There were differences between species and stage of maturity ( $P < 0.05$ ) in disappearance rates and extents. Fall growth was nearly equal in quality and digestibility to April growth, and maintained this quality throughout winter. Standing dead material was below NRC CP requirements (6 to 8%) year-round.

Cattle selected moderate microclimates for grazing and resting to avoid high winds and cold temperatures. They tended to remain in microclimates above the assumed lower critical temperature (LCT) of  $-23^{\circ}\text{C}$ , even though reference conditions often were below LCT. The availability of moderate microclimates may allow cows to continue grazing, thus maintaining forage intake, even when general conditions might otherwise cause them to defer grazing.

## CHAPTER 1

## INTRODUCTION

Wintering cattle in northern latitudes is the most costly aspect for livestock producers. Producing and feeding hay requires high inputs of time, labor, and capital. Grazing native range in winter, where possible, may help to reduce these costs. The major challenges to winter grazing in range livestock production systems in the northern latitudes are the generally low quality of forages and environmental stressors such as snow, cold temperatures, and wind.

For cattle, maintaining body condition through winter is difficult. The goal of management is to have a range cow in moderate to good condition at the beginning of winter and to try to either maintain that condition or minimize loss of condition so that calving is successful and rebreeding can occur without delay. The low quality of forage in general does not mature pregnant beef cow requirements. Energy and protein supplements are often fed to compensate for these deficiencies. Managing for adequate forage reserves on winter pastures would reduce the need for hay, except when snow cover limits forage availability. In years when fall growth is available in quantity, it could provide a source of high protein forage and may minimize the need for additional protein supplements.

Extreme cold and wind may further stress animals. Reduced grazing time and forage intake have been correlated with extreme cold, which may lead to loss

of condition. Shelter, either natural or manmade, can minimize the effects of these environmental stressors. In the open grasslands of the west, topography influences and creates microclimates over the landscape. Grazing animals may take advantage of these features to avoid extreme wind and cold.

There were two main objectives of this study. Our first objective was to assess the potential forage quality of the live and dead components of two co-dominant cool-season bunchgrasses to meet the nutritional requirements of cattle throughout the year. Our second objective was to determine if cows select moderate microclimates while foraging to minimize cold stress when environmental conditions are severe.

## CHAPTER 2

NUTRITIONAL VALUE OF LIVE AND DEAD COMPONENTS  
OF TWO BUNCHGRASS SPECIESIntroduction

Matching forage quantity and quality with demands of the grazing animal is a major challenge in rangeland production systems. Intake of metabolizable energy is potentially limiting in the early growing season, and intake of crude protein is potentially limiting during the dormant season (Senft et. al. 1987). In northern latitudes, severe winter weather can stress livestock (Webster 1970a, Christopherson et. al. 1979, Young 1985) grazing native range at a time when overall forage quality is low (Dragt 1985, Prescott 1990). Energy or protein supplements are fed to compensate for low forage quality, but at great cost, and with variable responses (Rittenhouse et. al. 1970, Kartchner 1981, Beverlin 1988, Sowell et. al. 1992). Potentially, fall growth when present in adequate amounts could provide an important source of high quality forage for winter grazing and thus minimize or even eliminate the need for additional protein supplements in some years.

The documented low quality of mature grasses in northern latitudes during winter is often based on analyses of the entire plant. Although herbivores are

able to select diets higher in quality than can be mimicked by hand clipping (Hardison 1954, Van Dyne 1965, Hart 1983, Karn and Hoffman 1989), in part by avoiding stemmy growth (Ganskopp 1992), the live and dead components of native bunchgrasses are seldom considered separately. Generally, the quality of native cool-season bunchgrasses declines as living material senesces; this material then becomes part of the dead component of the plant (McCall 1939, Stoddart 1945, Blaisdell 1952, Daer and Willard 1981). The quality of over-wintering standing dead continues to decline as a result of weathering processes (Blaisdell 1952). Uresk and Cline (1976) found higher mineral concentrations in live tissue compared with standing dead in bluebunch wheatgrass during seed development. Total nonstructural carbohydrate concentrations of bluebunch wheatgrass increase from summer dormancy through fall until the onset of winter, but concentrations in fall growth were not as high as those in spring growth (Daer and Willard 1981).

Cool-season species have the ability to initiate growth in spring and fall when conditions are favorable. During wet autumns, several researchers have noted the presence of new growth in bluebunch wheatgrass (Pseudoroegneria spicata[Pursh] Scribn. and Smith) (Blaisdell 1952, Quinton and McLean 1982) and Idaho fescue (Festuca idahoensis(Elmer) (McCall 1939). This growth, when present, may be as nutritious and palatable as new spring growth.

We determined the chemical composition and in situ digestibility of live and dead components of bluebunch wheatgrass and Idaho fescue. Our objective was to assess the ability of these forage components to meet animal requirements

throughout the year.

## Methods

### Study Site

The study site was a 150 hectare pasture on the Montana Agricultural Experiment Station Red Bluff Research Ranch (latitude 45°35', longitude 111°39') near Norris, Montana. The pasture has sandy and silty range sites typical of the foothills of southwestern Montana. Elevation ranges from approximately 1470-1740 m, with predominately southwest facing slopes. The prevailing southerly winds tend to blow the slopes free of snow during winter.

The pasture is dominated by a Festuca idahoensis/ Agropyron spicatum (currently classified as Pseudoroegneria spicata) habitat type with a Rhus trilobata/Festuca idahoensis habitat type limited to the lower southwest slopes of the major draws (Mueggler and Stewart 1980). Dominate forages of the pasture include bluebunch wheatgrass (Pseudoroegneria spicata), Idaho fescue (Festuca idahoensis), needle-and-thread grass (Stipa comata), and basin wildrye (Elymus cinereus). Scattered Rocky Mountain juniper (Juniperus scopulorum) occur on the lower slopes and limber pine (Pinus flexilis) occurs on the higher slopes. Annual precipitation averages 300 mm. Soils are Typic Argiborolls, sand and silt loams.

### Field Sampling

Individual bunchgrasses of each species were clipped bi-monthly from mid-

October 1991 to mid-April 1993 one week prior to in situ trials. Plants were clipped approximately 2 cm above soil surface which represents the portion of the plant readily available to ungulates. These samples were separated into live and dead material based on color, and allowed to air-dry.

### In situ Trials

The rate and extent of forage disappearance of the live, when present, and dead components were measured in situ using 4 mature, ruminally cannulated beef cows grazing the study pasture. Live and dead forage samples were separately ground through a Wiley Mill using a 2mm screen. For the in situ trials, 3 g samples of prepared material were placed in 15 x 20 cm bags made of 40 um mesh monofilament nylon. Only 2.5 g of Idaho fescue fall growth and spring growth were used in February and April 1993, respectively, because of limited availability. Ten bags of each forage type were placed in a mesh bag and suspended in the rumen of each cow. Animals were then allowed to forage on the study pasture. After intervals of 8, 24, 48, 72, and 96 hours, duplicate bags of each forage type were removed from each animal.

All bags were rinsed by hand with cold water until rinse water squeezed out of the bag was clear, then dried in a forced-air oven 48 hrs at 60 °C, and weighed. Bag residues from disappearance trials were analyzed for total Kjeldahl nitrogen (AOAC 1980) to determine extent of CP disappearance.

The dry matter (DM), crude protein (CP) (AOAC 1980), neutral detergent fiber (NDF), and acid detergent insoluble nitrogen (ADIN) (VanSoest and

Robertson 1980) contents of original samples for each forage type were determined and used as measures of forage quality.

### Rate Calculation and Analysis

Mertens and Loften's (1980) model was used to estimate in situ rate of dry matter (DM) disappearance:

$$R = D_0 e^{-k(t-L)} + U, \text{ when } t > L; \quad (1)$$

and

$$R = D_0 + U, \text{ when } 0 < t < L. \quad (2)$$

where  $R$  = percentage of DM remaining at time =  $t$ ,  $D_0$  = potentially digested DM fraction,  $k$  = disappearance rate constant,  $t$  = time of incubation,  $L$  = discrete lag time, and  $U$  = indigestible DM fraction.

A non-linear least squares regression equation was used to estimate disappearance rate (Mertens and Loften 1980, Nocek and English 1986, SAS 1988). To obtain initial estimates, the natural logarithm ( $\ln$ ) of the percentage of DM remaining was plotted as a function of incubation time.

Dry matter disappearance was adjusted for zero-hour disappearance (Nocek 1988). Duplicate nylon bags were prepared as above for each forage component and presoaked for 15 minutes in 39°C water. Fall growth samples were composited within species. Bags were hand rinsed, oven dried, and weighed as above. The percent dry matter lost was calculated and subtracted from the dry matter disappearance values of the in situ trials.

Dry matter rates and DM and CP extents were analyzed using the general liner model of SAS (1988) least-square means procedure. The main effects of species and stage of maturity, and the interaction of species and stage were determined within periods. Differences were considered significant when  $P < 0.10$  (Gill 1981).

#### Live-to-Dead Ratio

Fifteen plants of each species were randomly clipped from north, east, and southwest aspects of the pasture. Plants were clipped bi-monthly from April 1992 through April 1993. These were sorted into live and dead components and oven dried for 48 hrs at 60°C. Each component of each plant was weighed separately and the percent live component of the total plant was calculated on a dry-weight basis. Means and standard errors were calculated for each species and plotted by period.

## Results

### Composition of Forage Components

The two species were similar in chemical composition within forage component type and period. In general, CP concentrations decreased in live material as it matured. Idaho fescue retained live leaves through October and into winter. Thus its live component retained higher CP and lower ADIN in August and October than bluebunch wheatgrass (Table 1). Spring growth CP levels averaged above 20% for bluebunch wheatgrass and above 18% for Idaho fescue (Table 1).

**Table 1.** Percent crude protein (CP) of forage components.

Period	<i>P. spicata</i>			<i>F. idahoensis</i>		
	dead	live	fall	dead	live	fall
10/91	3.2	4.2	-	-	-	-
12/91	3.1	2.6 <sup>a</sup>	-	-	-	-
02/92	2.8	-	-	2.6	-	-
04/92	2.4	20.7	-	4.0	18.3	-
06/92	2.2	8.3	-	4.1	6.3	-
08/92	3.1	4.7	-	2.7	8.0	-
10/92	2.2	4.5	26.2	1.4	8.8	17.1
12/92	2.6	-	20.8	2.6	-	14.1
02/93	2.6	-	20.8	2.6	-	16.3
04/93	2.4	25.2	-	2.0	21.3	-

<sup>a</sup> This material was not truly live material, but current year's standing dead.  
 - Forage component not sampled

The composition of fall growth was similar to spring growth throughout winter. Fall growth CP levels remained high through winter ranging from 20.8 to 26.2% for bluebunch wheatgrass and 14.1 to 17.1% for Idaho fescue (Table 1). Crude protein of the standing dead of both species averaged 2.7% and varied little during the study.

The NDF and ADF values tended to increase in live material from April to June, and then drop slightly in August and again in October (Tables 2 and 3). In June, most reproductive culms (high cell wall and lignin content) were still part of the live component of the forage. In August and October, more of these culms had senesced and became part of the dead component. The remaining live material was composed mostly of leaves and vegetative tillers, and thus had slightly less fiber content. The NDF and ADF content of fall growth were similar to levels in spring growth of both species. Standing dead NDF and ADF values were slightly lower on average for Idaho fescue than for bluebunch wheatgrass. Values were highest in October samples of dead components for both species. By October all culms were considered dead, increasing the fiber content of the dead component.

Acid detergent insoluble nitrogen increased in live material from spring through fall in bluebunch wheatgrass. There was an increase in ADIN from April to June in Idaho fescue, and a slight decrease through August and October, probably caused by the proportion of reproductive culms in live material as described previously. The ADIN content was higher in fall growth than in April

**Table 2.** Percent neutral detergent fiber (NDF) of forage components.

Period	<i>P. spicata</i>			<i>F. idahoensis</i>		
	dead	live	fall	dead	live	fall
10/91	76.2	70.7	-	-	-	-
12/91	78.2	78.2	-	-	-	-
02/92	79.7	-	-	72.1	-	-
04/92	78.2	56.8	-	76.8	54.2	-
06/92	80.8	73.8	-	76.7	69.8	-
08/92	74.8	68.8	-	76.8	63.6	-
10/92	82.4	67.8	57.5	83.0	62.9	57.7
12/92	79.4	-	52.0	76.9	-	50.7
02/93	77.6	-	55.0	76.0	-	51.5
04/93	75.8	54.0	-	80.0	56.7	-

- Forage component not sampled

**Table 3.** Percent acid detergent fiber (ADF) of forage components.

Period	<i>P. spicata</i>			<i>F. idahoensis</i>		
	dead	live	fall	dead	live	fall
10/91	54.1	44.5	-	-	-	-
12/91	54.8	50.3	-	-	-	-
02/92	53.8	-	-	46.3	-	-
04/92	52.8	25.7	-	50.2	26.6	-
06/92	57.7	42.1	-	52.6	40.7	-
08/92	53.1	41.6	-	50.6	39.8	-
10/92	57.2	45.7	23.3	52.9	36.8	29.1
12/92	52.8	-	22.0	47.6	-	25.9
02/93	50.8	-	20.8	48.8	-	24.5
04/93	51.1	22.3	-	49.2	24.9	-

- Forage component not sampled

growth (Table 4). Standing dead ADIN was lower for Idaho fescue than for bluebunch wheatgrass on average, but varied considerably across periods, and no trends were evident.

**Table 4.** Acid detergent insoluble nitrogen (ADIN) as a percent of total kjeldahl nitrogen.

Period	<i>P. spicata</i>			<i>F. idahoensis</i>		
	dead	live	fall	dead	live	fall
10/91	38.1	16.3	-	-	-	-
12/91	31.2	24.6	-	-	-	-
02/92	30.0	-	-	17.6	-	-
04/92	29.7	2.9	-	14.4	2.4	-
06/92	35.3	7.5	-	18.2	7.5	-
08/92	27.2	16.2	-	27.0	7.4	-
10/92	41.7	16.9	4.4	46.5	6.9	5.2
12/92	34.2	-	3.7	23.1	-	3.5
02/93	29.9	-	3.2	24.4	-	3.5
04/93	32.6	2.8	-	29.0	3.5	-

- Forage component not sampled

### Rates and Extents

Generally DM rate constants were highest for April growth, and next highest for fall growth (Table 5). There was a main effect of stage of maturity ( $P < 0.05$ ) on DM rates during most periods (Table 6). Dry matter rate constants of live material tended to be higher than rates for dead components within sampling periods (Table 5). There were no differences between species except in October 1992 when rate constants were lower for Idaho fescue than for bluebunch

**Table 5.** Dry matter disappearance rates of forage components for each period. Value in parentheses is the standard error of the mean.

period	<i>P. spicata</i>		<i>F. idahoensis</i>		
	dead	live	dead	live	fall
10/91	0.042 (0.0036)	0.045 (0.0098)	-	-	-
12/91	0.037 (0.0040)	0.037 (0.0016)	-	-	-
02/92	0.027 (0.0018)	-	0.022 (0.0017)	-	-
04/92	0.037 (0.0016)	0.076 (0.0022)	0.032 (0.0038)	0.072 (0.0084)	-
06/92	0.034 (0.0035)	0.039 (0.0039)	0.040 (0.0034)	0.034 (0.0019)	-
08/92	0.039 (0.0024)	0.044 (0.0029)	0.037 (0.0012)	0.047 (0.0029)	-
10/92	0.031 (0.0026)	0.044 (0.0057)	0.024 (0.0014)	0.030 (0.0016)	0.049 (0.0056)
12/92	0.038 (0.0064)	-	0.030 (0.0028)	-	0.053 (0.0051)
02/93	0.035 (0.0043)	-	0.028 (0.0035)	-	0.060 (0.0062)
04/93	0.037 (0.0025)	0.098 (0.0092)	0.032 (0.0030)	0.101 (0.0055)	-

- Forage component not sampled.

**Table 6.** Summary of statistical significance for DM rate constants by period.

Source of Variation	1991		1992				1993			
	OCT	DEC	FEB	APR	JUN	AUG	OCT	DEC	FEB	APR
Species(S)	○	○	NS	NS	NS	NS	*	NS	NS	NS
Stage (St)	NS	NS	○	*	NS	*	*	*	*	*
S X St	○	○	○	NS	*	NS	NS	○	○	NS

NS Nonsignificant.

○ Only 1 species or 1 stage sampled.

\*  $P < 0.05$ 

wheatgrass ( $P < 0.05$ ). These lower rates may have been an artifact of sorting as described above. There was an interaction in June 1992. The rate constant was higher for live compared with dead material in bluebunch wheatgrass, but higher for dead compared with live in Idaho fescue. The chemical composition of the forage components does not seem to explain this interaction.

All possible species X stage interactions were significant for DM extent of disappearance ( $P < 0.05$ ) (Table 7). These interactions occurred because the difference in DM extents between the live and dead components of Idaho fescue

**Table 7.** Summary of statistical significance for DM extents by period.

Source of Variation	1991		1992				1993			
	OCT	DEC	FEB	APR	JUN	AUG	OCT	DEC	FEB	APR
Species(S)	○	○	*	*	*	*	*	*	*	*
Stage (St)	*	*	○	*	*	*	*	*	*	*
S X St	○	○	○	*	*	*	*	○	○	*

NS Nonsignificant.

○ Only 1 species or 1 stage sampled.

\*  $P < 0.05$

were greater than in bluebunch wheatgrass in April and June 1992, and April 1993, and greater in bluebunch wheatgrass than Idaho fescue in August and October. In general, DM extents tended to be greater for Idaho fescue than bluebunch wheatgrass (Table 8), and this is probably related to the lower NDF, ADF, and ADIN values associated with Idaho fescue. Live Idaho fescue tended to retain higher quality later in the growing season than live bluebunch wheatgrass, and thus was more digestible.

Dry matter extents adjusted for zero-hour residue loss were significantly less ( $P < 0.05$ ) for live compared with dead material within species because the fraction lost as soluble material and filtrate was much higher for live than dead components. Summer live forage lost 27 to 37% as soluble material and filtrate, and spring and fall growth lost 45 to 50%. Losses from the dead component of bluebunch wheatgrass were 13 to 18%, and 12 to 23% for the dead component of Idaho fescue (Table 8).

There was an interaction in periods April through October 1992. This was caused by greater differences in CP extents between live and dead components in April and June in bluebunch wheatgrass than in Idaho fescue. The opposite was true in August and October. Overall, CP extents were higher for live than dead components within species, and highest for spring and fall growth ( $P < 0.05$ ) (Tables 9 and 10). These differences may be related to the chemical composition of the live and dead components. Crude protein and ADIN were similar in dead of both species. Crude protein was higher in live bluebunch wheatgrass in April

**Table 8.** Dry matter disappearance extents (96 hrs) of forage components corrected for zero-hour for each period. Value in parentheses is the standard error of the mean.

period	<i>P. spicata</i>		<i>F. idahoensis</i>			
	dead	live	dead	live	live	fall
10/91	44.4(0.92) 18 <sup>a</sup>	37.0(1.76) 27	-	-	-	-
12/91	44.1(0.97) 18	37.8(1.20) 18	-	-	-	-
02/92	42.3(0.71) 16	-	56.5(0.35) 23	-	-	-
04/92	49.5(0.48) 16	45.4(0.13) 46	62.7(0.61) 18	41.8(0.03) 50	-	-
06/92	48.4(0.71) 15	41.7(0.35) 30	61.6(0.30) 18	42.9(0.71) 33	-	-
08/92	49.6(0.38) 18	35.2(0.53) 30	53.3(0.28) 19	42.4(0.35) 37	-	-
10/92	44.0(0.75) 13	28.7(0.52) 37	54.0(0.73) 13	50.6(0.31) 27	34.8(0.34) 45	-
12/92	41.8(2.18) 14	-	59.2(0.99) 12	-	31.2(1.33) 45	-
02/93	44.3(0.94) 16	-	48.8(0.86) 18	-	32.5(0.97) 45	-
04/93	47.0(0.44) 15	46.6(0.06) 45	60.9(0.72) 13	43.1(0.10) 48	-	-

<sup>a</sup> Percent lost as soluble material and filtrate from zero hour bags.

- Forage component not sampled.

**Table 9.** Summary of statistical significance for CP extents by period.

Source of Variation	1991		1992				1993			
	OCT	DEC	FEB	APR	JUN	AUG	OCT	DEC	FEB	APR
Species(S)	○	○	*	*	*	*	NS	*	**	NS
Stage (St)	*	*	○	*	*	*	*	*	*	*
S X St	○	○	○	*	*	*	*	○	○	NS

NS Nonsignificant

○ Only 1 species or 1 stage sampled.

\*,\*\* P<0.05, P<0.10 respectively

and June than in live Idaho fescue, and ADIN was similar for live components of both species during these periods. However, CP was nearly twice as high and ADIN was less than half in live Idaho fescue compared with live bluebunch wheatgrass in August and October.

Crude protein extents should be interpreted with caution. Microbial CP contamination has been demonstrated to increase with increasing incubation time in situ, resulting in a lower apparent extent of disappearance (Olubobokun et. al. 1990).

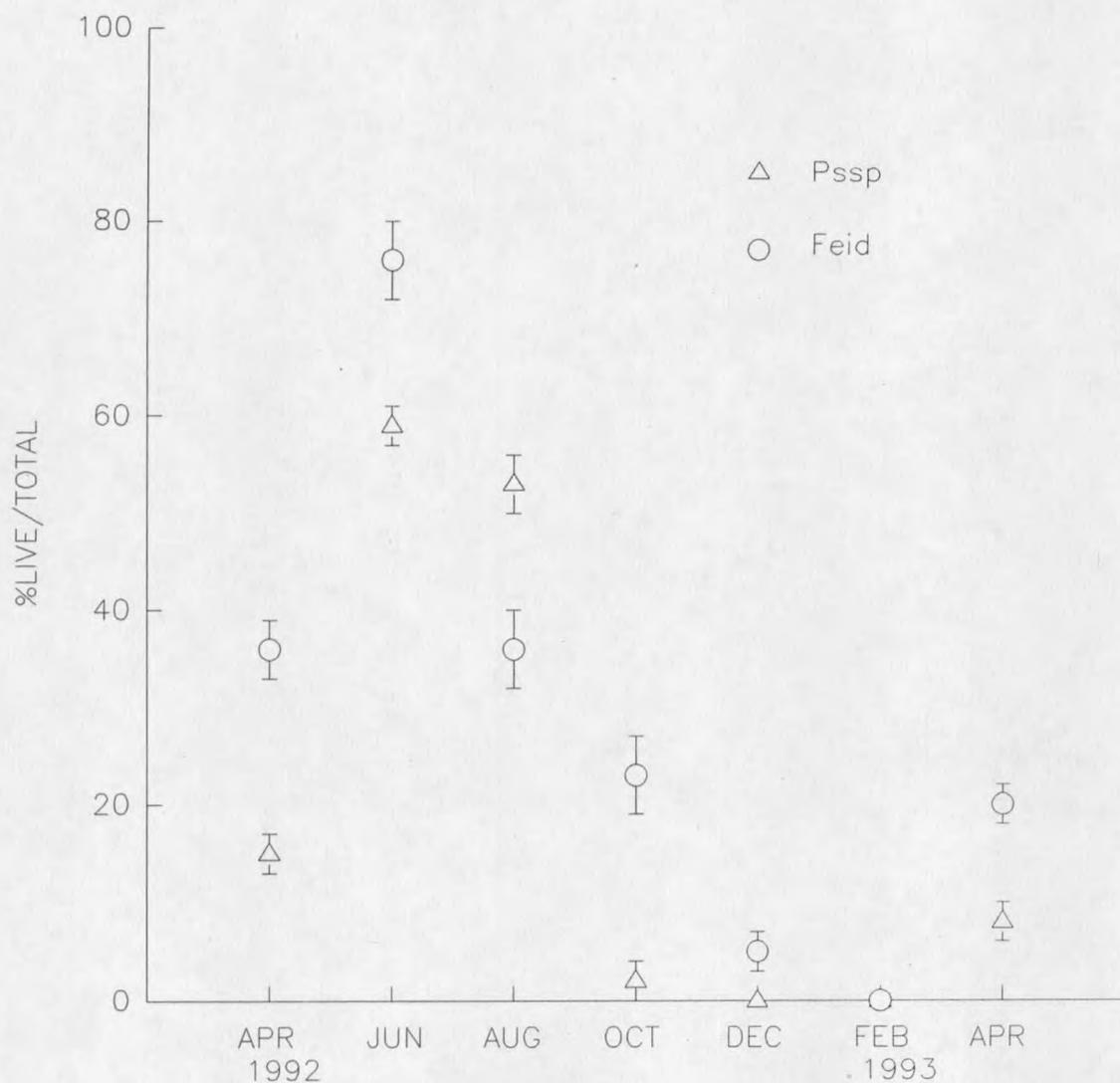
#### Live-to-Dead Ratio

There was a greater proportion of live-to-dead material in Idaho fescue than in bluebunch wheatgrass in April of 1992 and 1993 (Figure 1). The proportion of live material peaked in June in both species, declining through the rest of the year until spring. Fall growth was not abundant either year, but was more common in Idaho fescue than in bluebunch wheatgrass.

**Table 10.** Crude protein disappearance extents (96 hrs) of forage components for each period. Value in parentheses is the standard error of the mean.

period	<i>P. spicata</i>		<i>F. idahoensis</i>		
	dead	live	dead	live	fall
10/91	43.0 (1.57)	63.7 (2.38)	-	-	-
12/91	55.9 (2.44)	46.2 (1.90)	-	-	-
02/92	45.8 (1.00)	-	63.7 (1.71)	-	-
04/92	61.2 (0.59)	98.3 (0.12)	83.8 (0.20)	98.3 (0.07)	-
06/92	43.6 (1.49)	83.2 (0.13)	79.1 (1.44)	84.9 (0.27)	-
08/92	66.3 (1.12)	73.3 (0.29)	63.4 (1.31)	91.1 (0.28)	-
10/92	37.9 (2.36)	75.6 (0.50)	20.8 (4.17)	92.4 (0.23)	95.1 (0.25)
12/92	48.8 (2.66)	-	66.2 (2.86)	-	94.9 (0.90)
02/93	56.7 (3.05)	-	61.8 (1.32)	-	95.4 (0.38)
04/93	58.0 (0.84)	98.7 (0.003)	60.0 (1.49)	98.5 (0.04)	-

- Forage component not sampled.



**FIGURE 1.** Live growth as a percent of total above ground biomass (2.5 cm stubble height) on a dry matter basis. Error bars indicate standard error of the mean. Live growth in October, December, and February is a composite of retained green leaves and fall growth.

### Discussion

Cattle grazing native range may be deficient in energy and protein during the dormant season (Senft et. al. 1987). This is mainly because dormant forage is lower in energy and protein than live forage. Thermal stress increases the energy required for maintenance (Blaxter 1967, Webster 1970a, Ames et. al. 1980), and protein demand increases as pregnancy advances (NRC 1984). Webster (1970a) estimated that mature cows exposed to cold require as much as 81 Mcal more energy during winter than cows kept indoors. Although low in energy content, standing dead material provides roughage, is high in cell wall content (NDF) and has a high heat increment of feeding (Meyer and Lofgreen 1956, Moen 1973, Ames et.al. 1980). The 'work of eating' produces heat; more heat is produced eating dried forages compared with fresh forages (Osuji 1974). Eating and ruminating time increase with increasing concentrations of cell wall in forage (Welch 1975). This results in increased heat production, which aids thermoregulation during winter (Webster 1978).

Crude protein of the standing dead component of bluebunch wheatgrass and Idaho fescue were well below the NRC (1984) requirements of 6-8% for mature beef cows at all times of year. Rumen microflora need a minimum of 50 mg ammonia nitrogen per liter of rumen fluid for maximum growth in vitro for concentrate feeds (Satter and Slyter 1974). This requirement is less for fibrous

feeds (Orskov 1982). Low quality roughages have higher NDF and lower energy content, thus the potential extent of disappearance and subsequent microbial requirement for nitrogen is lower. Addition of non-protein nitrogen (NPN) to a diet does not increase the potential extent of disappearance of a forage, but simply provides rumen micro-organisms with the necessary nitrogen to attain that potential (Orskov 1982).

Providing protein supplement to mature cattle on low quality roughage diets may be of little economic benefit in mild winters when forage is readily available (Kartchner 1981). If they enter the winter in good condition, cows on low planes of nutrition during late pregnancy can calve successfully and cow and calves can have compensatory weight gains when provided with a high quality diet after calving (Jordan 1968a, 1968b, Russel 1979, Sowell et. al. 1992).

Dry matter rate constants were generally lower for dead than live material, however there were no clear trends in rate constants within dead material throughout the year. Using the in situ technique, nylon bags are artificially retained in the rumen and in situ disappearance rates do not reflect the influence of passage rate on digestibility. Passage rates are slower for low quality than high quality forages (Van Soest 1982). In vivo, reticulorumen motility and ruminating increases with colder temperatures, decreasing retention time and increasing passage rate resulting in an apparent decrease in digestibility of energy and protein (Christopherson 1976, Gonyou et al. 1979, Johnson et al. 1987). In contrast, Christopherson (1976) found a decrease in DM digestibility in calves and

sheep, but no decrease in DM digestibility in mature cows when they were exposed to four weeks of  $-11^{\circ}\text{C}$ , possibly because of their larger body size.

Fall growth was not abundant nor uniformly available during the study, but was high in CP content and CP extent of disappearance. Extent of disappearance is a measure of total digestibility of a forage and is more closely correlated to chemical composition of a forage (Smith et al. 1972). Adequate amounts of fall growth would provide a high protein forage for winter grazing, complementing the roughage provided by the standing dead component. Increased crude protein in the diet tends to increase the digestibility of forage and thus increases available energy (Rittenhouse et al. 1970, Ames et al. 1980):

Fall growth was lower in DM extent and rate of disappearance than April growth. In situ digestibility is a relative measure of digestibility within a forage type (Kartchner and Campbell 1979). Dry matter digestibility of a forage is more closely correlated to CP content than to other chemical properties in grasses (Burzlaff 1970, Holocek et al. 1982), and negatively correlated to lignin, ADF, and NDF (Van Soest 1982). The slightly lower CP and higher ADIN in fall growth compared with April growth may have accounted in part for the lower DM rate and extent of disappearance. Also, perhaps the rumen microbial populations that were adjusted to the low quality of the predominantly dead material in late fall and winter diets were less efficient at fermenting fresh green material. Live material was generally more abundant in spring and the population of rumen microorganisms would have adjusted accordingly (Orskov 1982).

Idaho fescue retained green leaves over winter. This material was not sampled through winter, but the late October CP content and disappearance and ADIN content were similar to values in June and August. McCall (1939) found that CP content of over-wintering green material is similar to mid-summer values. Dragt and Havstad (1987) observed over-wintering green leaves in Idaho and rough fescue (*Festuca scabrella*) and suggested this may partially explain why elk prefer these species in winter over bluebunch wheatgrass, which did not retain green material through winter.

Spring growth was high in CP, and low in ADIN and fiber. April growth had higher rate constants compared with fall growth. New growth in spring and fall is predominately vegetative, with a high leaf to stem ratio. Generally, leaves are more digestible than stems (Lentz and Buxton 1991). Lactating cows have higher protein requirements (NRC 1984), and benefit from this high protein and highly digestible forage component after calving in spring.

Management opportunities exist for enhancing the forage base in the fall by increasing the amount of fall growth to dead material. Pastures grazed in early spring could still be used for late fall and winter grazing. Removal of standing dead by early spring grazing increases availability of fall growth in bluebunch wheatgrass (Pitt 1986). Pitt (1986) observed that late spring grazing of bluebunch wheatgrass delayed phenology of subsequent fall growth, thus maintaining higher quality into the fall. Summer grazing, however, resulted in no significant differences in chemical composition of winter forage in bluebunch wheatgrass or

Idaho fescue (Dragt and Havstad 1987). Burning Idaho fescue in late summer when soil moisture is high stimulates fall growth (Britton et. al. 1983). However this would also destroy the standing dead material, which may be beneficial as a source of roughage.

Proper management of rangelands may promote the desired amounts of live and dead components of grasses, allowing native range to better meet the nutrient requirements of cattle on a year round basis. At times, supplemental feeding will be necessary. On fall-winter range, protein supplementation guides could be developed by monitoring the ratio of live-to-dead components. The constituent differential method described by Gillen and Tate (1993) may be a practical and efficient method for determining the relative amounts of live and dead biomass.

Managing for adequate forage reserves on fall-winter range is important. Snow cover may limit availability of forage. Plants with an abundant amount of tall standing dead are more accessible to cows than forage beneath the snow. In open winters or in areas where snow blows free of the range, fall growth would be most accessible. Proper management aimed toward matching the changing nutrient demands of the animal with changing forage quality of the live and dead components could sustain animal and range productivity while using lower inputs.

## CHAPTER 3

CATTLE USE OF MICROCLIMATES ON A NORTHERN LATITUDE  
WINTER RANGEIntroduction

Grazing native range can help lower the costs of wintering livestock. In the northern latitudes, forage quality is low in winter, and severe weather may further stress livestock. Extreme cold and wind can negatively affect an animal's thermal balance, increasing energy demand (Webster 1970). Partly because of this increased demand for energy, cattle lose weight or have lower weight gains when exposed to cold (Webster 1970b, Hiridoglou and Lessard 1971). Cold and wind have been correlated to a decrease in grazing time and forage intake, which may result in a loss of condition and reproductive potential of range cows (Malechek and Smith 1976, Adams 1989). These effects can be minimized if cattle are provided with adequate shelter, either natural or manmade (Webster 1970).

In the relatively open grasslands of the west, topography is a primary factor influencing microclimatic differences over a landscape. Low lying areas are sheltered from the prevailing winds by the surrounding uplands. South-facing aspects receive more solar radiation than north-facing aspects. There are also temperature differences associated with changes in elevation. Free-ranging cattle

may exploit these differences in topography and microclimate to minimize or avoid environmental stressors such as high winds and cold temperatures.

Foraging takes priority over thermoregulatory behavior in free-ranging animals (Ingram and Dauncy 1985). However, in extreme weather thermoregulatory behavior may override foraging. Cattle will defer grazing when cold stressed until it becomes warmer (Malechek and Smith 1976), and select resting sites to avoid extreme wind in winter (Senft and Rittenhouse 1985a).

We investigated cattle selection of microclimates in response to cold stress over a six week period for two consecutive winters. Our objective was to determine if cows respond to extreme wind and cold by selecting moderate microclimates for foraging.

## Theory and Methods

### Thermoneutral Zone and Lower Critical Temperature

Animals exchange heat with their environment. This is a dynamic process of balancing heat gain with heat loss (Moen 1973). Maintaining this balance results in a relatively constant body temperature in endotherms. There is a range of environmental temperatures within which metabolic heat production (MHP) is independent of the ambient temperature (Young 1985). This range of temperatures, or thermoneutral zone (TNZ), varies among species and even among individuals, depending on size, sex, age, level of nutrition and previous acclimatization (Webster 1970a, Webster 1971, Christopherson 1979, Young 1985, Senft and Rittenhouse 1985b). The lower critical temperature (LCT) of this range is the temperature below which animals become cold stressed whereby they must either increase MHP or conserve heat to maintain homeostasis (Moen 1973). If the ambient temperature remains below the individual's LCT for an extended period of time, and MHP production can no longer compensate for heat loss, hypothermia may compromise the health, reproductive potential, and even the life of the individual.

### Standard Operative Temperature

Environmental factors other than ambient temperature influence the thermal environment of an animal. Extreme fluctuations in temperature, solar

radiation, wind, and precipitation can either help or hinder thermoregulation. (Webster 1971, Moen 1973, Ames 1975, Senft and Rittenhouse 1985).

Parker and Gillingham (1990) developed a model to estimate critical thermal environments for mule deer (Odocoileus hemionus hemionus). They initially used an equation presented by Campbell (1977) to estimate operative temperature ( $T_e$ ):

$$T_e = T_a + [r_e(R_{abs} - \epsilon_s \sigma T_a^4)] / \rho c_p \quad (1)$$

Operative temperature includes ambient temperature ( $T_a$ ) and the effects of wind and radiation on the animal. These effects incorporate solar and thermal radiation absorbed ( $R_{abs}$ ), thermal radiation emitted ( $\epsilon_s \sigma T_a^4$ ), the animal's resistance ( $r_e$ ) to convective and radiative heat transfer, and the density ( $\rho$ ) and specific heat ( $c_p$ ) of the air. Parker and Gillingham (1987) determined, however, that it underestimated the influence of wind on coat resistance of mule deer at high wind speeds. Thus, they used standard operative temperature ( $T_{es}$ ) (Bakken 1981) to estimate the animal's thermal environment:

$$T_{es} = T_b - [(r_{Hbs} + r_{es}) / (r_{Hb} + r_e)] \times (T_b - T_e) \quad (2)$$

where  $T_{es}$  is the standard operative or wind-chill corrected temperature experienced by the animal (Parker and Robbins 1984) and  $T_b$  is the body temperature of the animal. The animal's resistance to convective and radiative heat transfer is expressed as a ratio of coat and tissue resistances ( $r_{Hbs}$ ) and

boundary layer resistance ( $r_{eS}$ ) without wind ( $\mu \leq 1 \text{ m s}^{-1}$ ) to these resistances ( $r_{Hb} + r_e$ ) under natural outdoor wind speeds (see Appendix).

As  $T_{eS}$  decreases, either as a response to increasing wind speed or decreasing  $T_e$ , whole body thermal resistance increases (Parker and Robbins 1984). This is mainly caused by vasoconstriction of subcutaneous blood vessels in the skin, reducing blood flow and the amount of convective heat lost to external tissue and thus to the environment (Webster 1974a). The standard operative temperature at which whole body thermal resistance attains a maximum value corresponds to an animal's LCT (Parker and Robbins 1984).

The standard operative temperature that is equivalent to an animal's LCT can be used as a reference point to determine which environmental conditions (combinations of  $T_e$  and  $\mu$ ) may cold stress the animal. Wind can be measured directly using an anemometer, and  $T_e$  may be estimated based on direct measures with a black globe thermometer (Bakken 1992).

### Theory of the Black Globe Thermometer

Radiant energy is an important source of heat for animals (Walsberg 1992). Short-wave radiation from the sun and long-wave radiation emitted from sky, earth and terrestrial objects influence the radiant heat load at a site but are difficult to measure. A black globe thermometer is influenced by these sources of radiation. A black globe thermometer is in equilibrium with its environment when heat gained (or lost) equals heat lost (or gained). This equilibrium temperature is an estimate of  $T_e$  (Kuehn et. al. 1970). The difference between

$T_e$  and  $T_b$  equals the net thermal gradient between the animal and its environment (Walsberg 1992).

Bakken (1992) stated that hollow copper models of the animal with a centrally-located thermistor provide an approximate value for  $T_e$ , but should be checked against values from freshly-killed specimens or a life-size taxidermic mount, which was not possible in this study.

For this study, we constructed blackglobe thermometers from 10.2 cm copper ball cocks, painted mat black. A thermometer was inserted through a black rubber stopper, which was then inserted into the copper sphere so that the thermally sensitive end of the thermometer was in the center of the sphere (Renecker and Hudson 1986, Yousef 1989). Given the small size of the blackglobe it may gain heat more rapidly than a cow. However, the smaller boundary layer of the globe would also allow it to cool more rapidly by convection, at least partially off-setting heat gain (Campbell, pers. comm.). These thermometers were used to estimate  $T_e$  of the microclimate at cow location and at fixed monitoring points.

#### Model of Lower Critical Temperature

As a reference point for cold stress, we developed a model of LCT for cattle relative to  $T_e$  and  $u$ , adapted from Parker and Gillingham's (1990) model of the thermal environment for mule deer. We simplified their model to estimate the combinations of  $T_e$  and  $\mu$  that result in a  $LCT = T_{es} = -23^{\circ}\text{C}$ . Estimates of the LCT for a 500 kg beef cow range from  $-13^{\circ}\text{C}$  in early pregnancy to  $-26^{\circ}\text{C}$  in

late pregnancy to  $-47^{\circ}\text{C}$  during lactation (Christopherson 1985). Study cows were in moderate body condition and acclimated to winter conditions.

Bakken (1980) simplified the equation for standard operative temperature as:

$$T_{es} = T_b - (K_e/K_{es})(T_b - T_e) \quad (3)$$

where  $K_e/K_{es}$  is the ratio of overall thermal conductance of the animal in the reference environment ( $K_e$ , essentially no wind) to the outdoor environment ( $K_{es}$ ) respectively. Wind speed is the principal environmental factor affecting the ratio  $K_e/K_{es}$  (Bakken 1992). Once the influence of wind on  $K_e/K_{es}$  is determined experimentally,  $T_{es}$  can be calculated from measured values of  $T_e$  and wind speed ( $\mu$ ) (Bakken 1992).

Because  $T_{es}$  is a constant in this model, and wind speeds could not be controlled, it was not possible to use a black globe thermometer to estimate  $T_e$ . By setting  $T_{es}$  equal to  $-23^{\circ}\text{C}$ , and varying wind speed in the resistance term ( $K_{es}/K_e$ ), we can solve equation (3) for  $T_e$ .  $\text{LCT} = -23^{\circ}\text{C}$  was then plotted relative to  $T_e$  and  $\mu$  and used as a reference for cold stress. Solving for  $T_e$  in eq.(3) gives:

$$T_e = T_b + (K_{es}/K_e)(T_{es} - T_b) \quad (4)$$

Body temperature ( $T_b$ ) for cattle was assumed to be constant at  $38.6^{\circ}\text{C}$ . Body temperature may be elevated as a response to high operative temperature

but is relatively constant at low temperatures in wild ungulates (Parker and Robbins 1984). Christopherson (1979) found that rectal temperatures in yearling Herefords did not change more than a few tenths of a degree from  $38.6^{\circ}\text{C}$  when ambient temperatures dropped from  $10^{\circ}\text{C}$  to  $-30^{\circ}\text{C}$ .

Resistance ratios ( $K_{es}/K_e$ ) were calculated using Parker and Gillingham's (1990) equations for whole body thermal resistance of mule deer ( $r_{Hb}/r_{Hbs}$ ) in winter over a range of wind speeds from 0 to  $15 \text{ m s}^{-1}$ . Boundary layer resistance ( $r_e$ ) is minimal relative to coat and tissue resistance (Campbell 1977), particularly in windy conditions, and was considered to be negligible. Thermal resistances ( $r_{Hb} + r_e$ ) for mule deer and elk were similar within a range of  $-20$  to  $38^{\circ}\text{C}$  (Parker and Robbins 1984). Resistance values for cattle are similar to those for elk (Monteith and Unsworth 1990). Therefore, this simplification of Parker and Gillingham's (1990) model should approximate  $T_{es}$  for cattle.

### Windchill

Windchill incorporates the combined effects of ambient temperature and wind, and influences the thermal balance of an animal (Ames and Insley 1975). Windchill was calculated specifically for cattle with a winter haircoat using an equation developed by Ames and Insley (1975):

$$\text{Windchill}(^{\circ}\text{C}) = 0.996T_a - 0.811\mu + 0.028\mu^2 - 0.0077\mu^3 \quad (5)$$

where  $T_a$  is in  $^{\circ}\text{C}$ ,  $\mu$  is in  $\text{miles h}^{-1}$  ( $0.45 \text{ m s}^{-1}$ ).

Windchill is accurately calculated using wind run (Ames, pers. comm.), or total distance of wind passing a fixed point per unit time. In this study, values were based on average wind speeds recorded over 10 second intervals.

### Study Site

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 typical of the foothills of southwestern Montana. Elevation ranges from approximately 1520 - 1770 m. The pasture has predominately southwest facing slopes which typically blow free of snow by prevailing southwest winds, making forage accessible year round. The topography also provides a range of microclimates. The pasture is dominated by a Festuca idahoensis/ Agropyron spicatum habitat type with Rhus trilobata/ Festuca idahoensis habitat type limited to southwest slopes of the major draws (Mueggler and Stewart 1980). Scattered Rocky Mountain juniper (Juniperus scopulorum) occur on lower slopes whereas limber pine (Pinus flexilis) occurs on the upper slopes. Springs in three separate draws, two low and one higher up in the pasture, provide water. Geothermal processes kept these heated just enough to remain free-flowing through most of the winter.

### Study Design

Three transects of four permanent monitoring points were established across a major northwest-southeast draw in the pasture. Point 1 of each transect

was on a bench on the west side of the draw, point 2 was in the bottom of the draw, points 3 and 4 were mid-slope and on an exposed ridge, respectively, and on the east side of the draw. We placed these fixed points at topographic extremes to measure the range of microclimates available in the pasture. The number of fixed points (12) was constrained by the amount of time necessary to monitor them.

One blackglobe and one dry-bulb thermometer were attached with a buret clamp to a steel fence post at each point, and were placed approximately at shoulder height (1.3 m) of a mature cow (Yousef 1989). The dry-bulb thermometer was inserted through a rubber stopper and a heavy aluminum foil guard was attached to this. The aluminum guard reflects direct solar radiation away from the thermally-sensitive end of the thermometer. A hand-held anemometer was used to record average wind speed over a 10 second interval at each point.

Pregnant Angus x Hereford range cows from 4 to 12 years of age grazed the pasture from mid-December to early-February. Six cows grazed the pasture in 1991-92 (Winter 1) whereas eleven grazed it in 1992-93 (Winter 2). In Winter 1 cows were fed a pelleted protein supplement ( $0.9 \text{ kg day}^{-1}$ ) at the end of the last observation period. Supplement was fed at the cows' current location to avoid disrupting their grazing pattern. Cows were not supplemented in Winter 2. Ambient temperature, blackglobe temperature, and windspeed were recorded at each point and at the concurrent cow location three times per day at

approximately 0800h, 1200h, and 1530h, three days per week over a six-week period from late December to early February in 1991-92 and 1992-93.

In Winter 1, cow microclimate, location, and activity (grazing, resting) were recorded after the fixed points. Locating six cows in a rugged 150 ha pasture often required extra time. In Winter 2, cow location and microclimate were recorded first, and fixed points were read immediately thereafter, minimizing total monitoring time. Elapsed time for measuring and recording fixed points and cow location averaged 45 minutes to 1 hour. Microclimate data from an exposed fixed monitoring point (1620 m elevation) in the approximate center of the pasture was used as a reference for general weather conditions in the pasture. Cow location was classified as protected (draw), moderately protected (lower slopes), or exposed (bench, upper slopes and ridgetops) relative to topography, prevailing wind direction, and reference climate.

Activity was expressed as a percentage of the total observations in which all or at least half of the cows were involved in the activity. We did not record the activity of individual animals, or quantify daily grazing or resting time.

An automated weather station approximately 1.6 km north of the study site recorded ambient temperature, solar radiation, and wind speed on a 24 hour basis. Data from the station were used to supplement the manually-collected data.

### Results

Mean monthly temperatures were above normal during the winter of 1991-92 (Winter 1), the lowest recorded temperature during the study period was  $-12^{\circ}\text{C}$  (Table 11). Most days were above  $0^{\circ}\text{C}$ . The 1992-93 (Winter 2) study period was more typical of winter in this region. A low of  $-24^{\circ}\text{C}$  was recorded and most days were below  $0^{\circ}\text{C}$  during the study period. Wind speeds ranged from 0 to  $13\text{ m s}^{-1}$  both years, indicating that the southerly wind is a stable feature of the site.

Table 11. Mean ambient temperature in  $^{\circ}\text{C}$  by month for each study period.

Winter	December	January	February
1	-1.6	-1.9	2.2
2	-7.3	-7.8	-7.0
Norm <sup>a</sup>	-3.4	-6.0	-2.6

<sup>a</sup>30 year average (1951-1980), Montana State Climate Center, Station 1044, Bozeman, MT

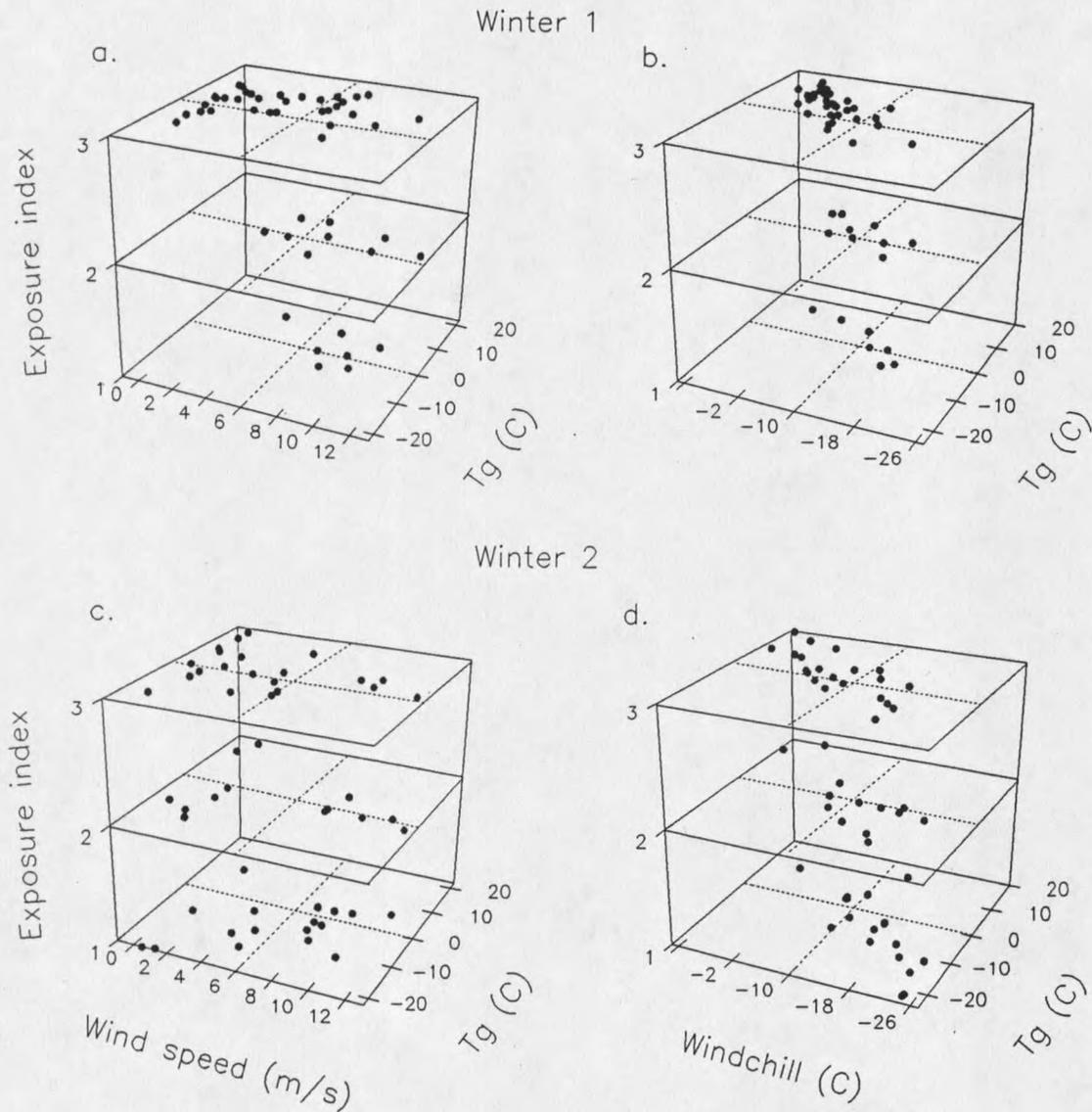
Microclimates at cow locations were usually within the range of microclimates of fixed points with few exceptions. Winter 1 'cow' temperatures were outside this range by  $1.5^{\circ}\text{C}$  for 16% of the observations, and by  $2.5^{\circ}\text{C}$  for only 6% of the observations. These exceptions were mostly caused by time delays associated with locating the cows. Only on one occasion did wind speed at cow location vary appreciably ( $> 2.0\text{ m s}^{-1}$ ) outside the range of wind speeds, when cows were in an aspen grove. In winter 2, cows were outside of this range on only

one occasion, when cow  $T_g$  was  $5^{\circ}\text{C}$  cooler than the range of temperatures because conditions changed rapidly from overcast to full sunshine at mid-day.

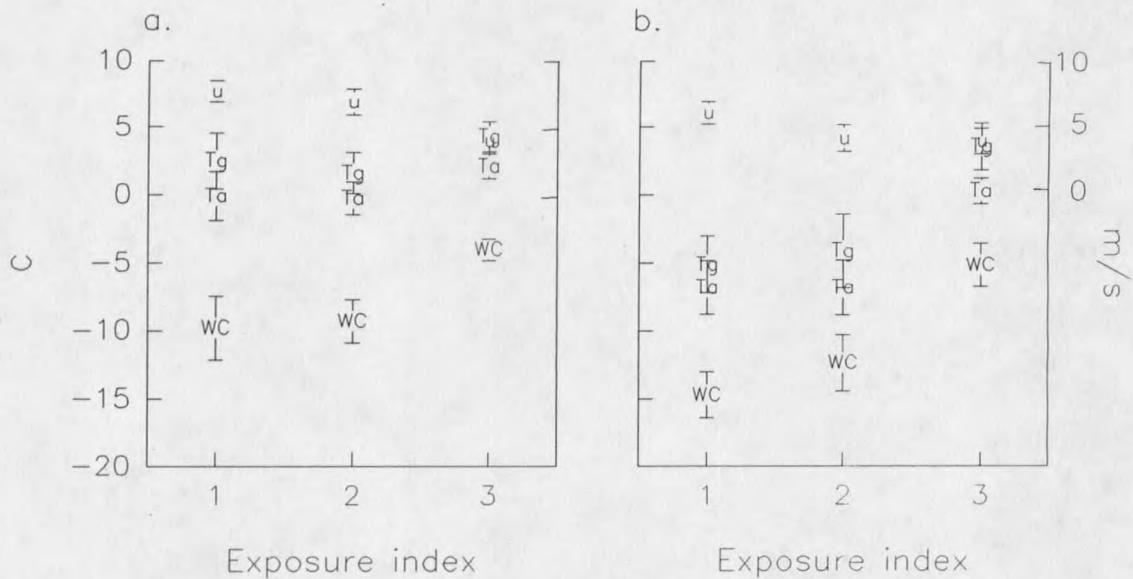
Microclimates, as affected by topography, influenced winter use patterns (Figure 2). At higher wind speeds and colder temperatures ( $T_g$ ), cows tended to seek protected and moderately protected areas (Figures 2a, c; planes 1 and 2). This becomes even more apparent when windchill is considered (Figures 2b, d). Mean windchill temperatures of reference climate when cows were in protected and moderately protected areas were less than mean windchill temperatures when cows were in exposed areas (Figures 3a, b).

The reference climate was often below the lower critical temperature (LCT=-23), particularly in Winter 2 (Figures 4d, 5d). Cows tended to avoid these extremes, using microclimates which allowed them to remain above their LCT most of the time (Figures 4a-c, 5a-c). When the reference climate was below LCT, cows were predominantly in protected or moderately protected areas of the pasture (Figures 4d and 5d).

Cattle-use was well distributed throughout the pasture over both study periods, except that they tended to avoid using the higher slopes in Winter 2, probably because of the colder conditions (Figure 6). Cows were observed grazing approximately 70% of the sampling time of both winters. In Winter 1, most of the grazing and resting occurred in exposed areas (Table 12). In Winter 2, grazing was more evenly distributed among the three levels of exposure, but cattle rested more in protected and moderately protected areas.



**Figure 2.** Measured environmental variables ( $T_g$ ,  $\mu$ ) at a fixed reference point in the pasture in Winter 1 (a and b) and Winter 2 (c and d). Horizontal planes represent exposure of cows to reference climate based on cow location in the landscape. Exposure index key: 1=protected (draw), 2=moderately protected (lower slopes), and 3=exposed (upper slopes and ridges). Windchill (b and d) combines ambient temperature ( $T_a$ ) and wind speed.



**Figure 3.** Mean environmental conditions of reference climate for each exposure index of cattle (planes 1, 2, and 3 of Figure 2) during (a) Winter 1 and (b) Winter 2. Exposure Index: 3=exposed, 2=moderately protected, 1=protected. Variables are wind speed ( $u$ ), black globe temperature ( $T_g$ ), ambient temperature ( $T_a$ ), and windchill (WC). Error bars indicate standard error of the mean.

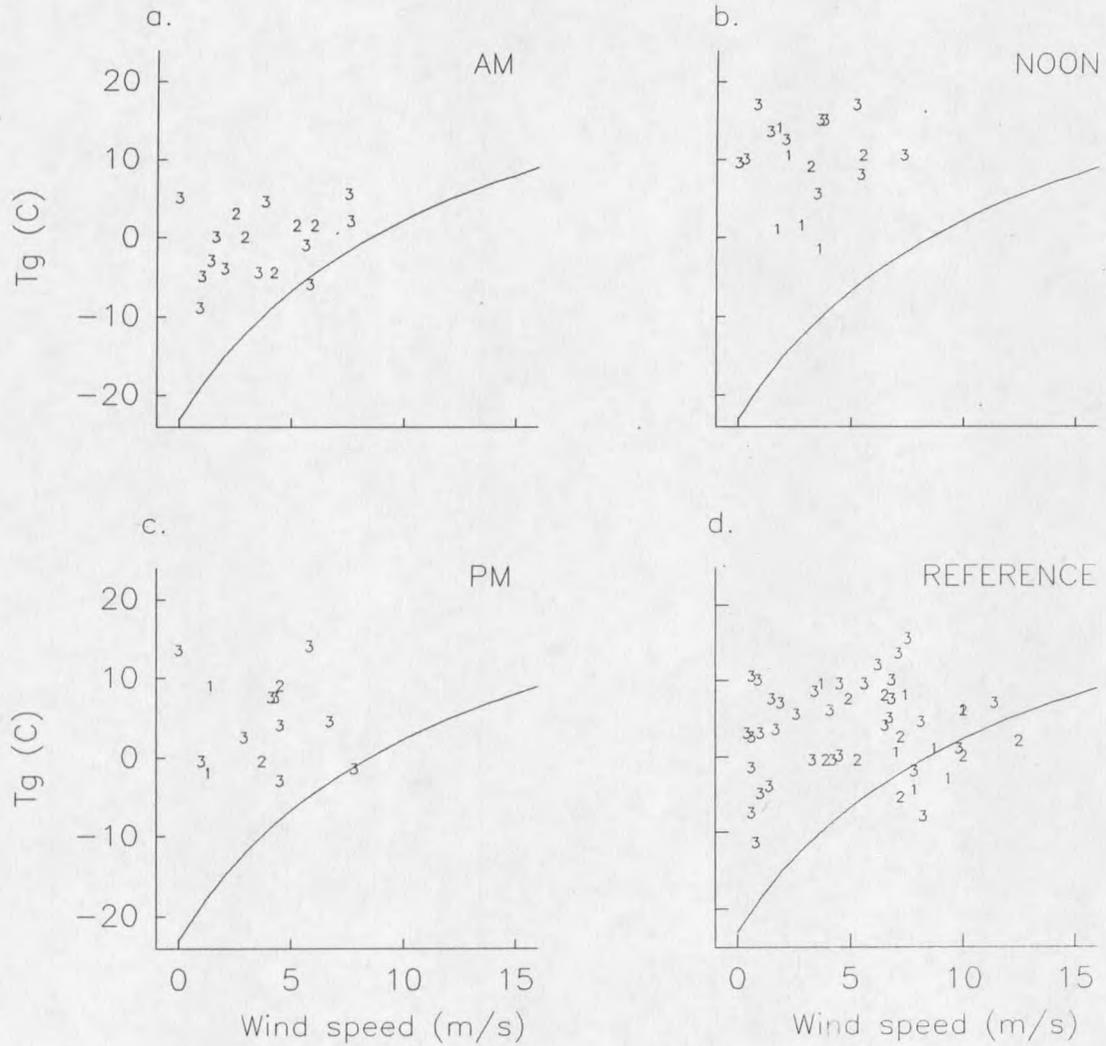
**Table 12.** Percent of observations in which all or at least half of cows were grazing or resting by level of exposure (EI).

EI <sup>a</sup>	Winter 1 <sup>b</sup>		Winter 2 <sup>c</sup>	
	Grazing	Resting	Grazing	Resting
3	45	23	37	13
2	14	4	12	7
1	10	4	19	12

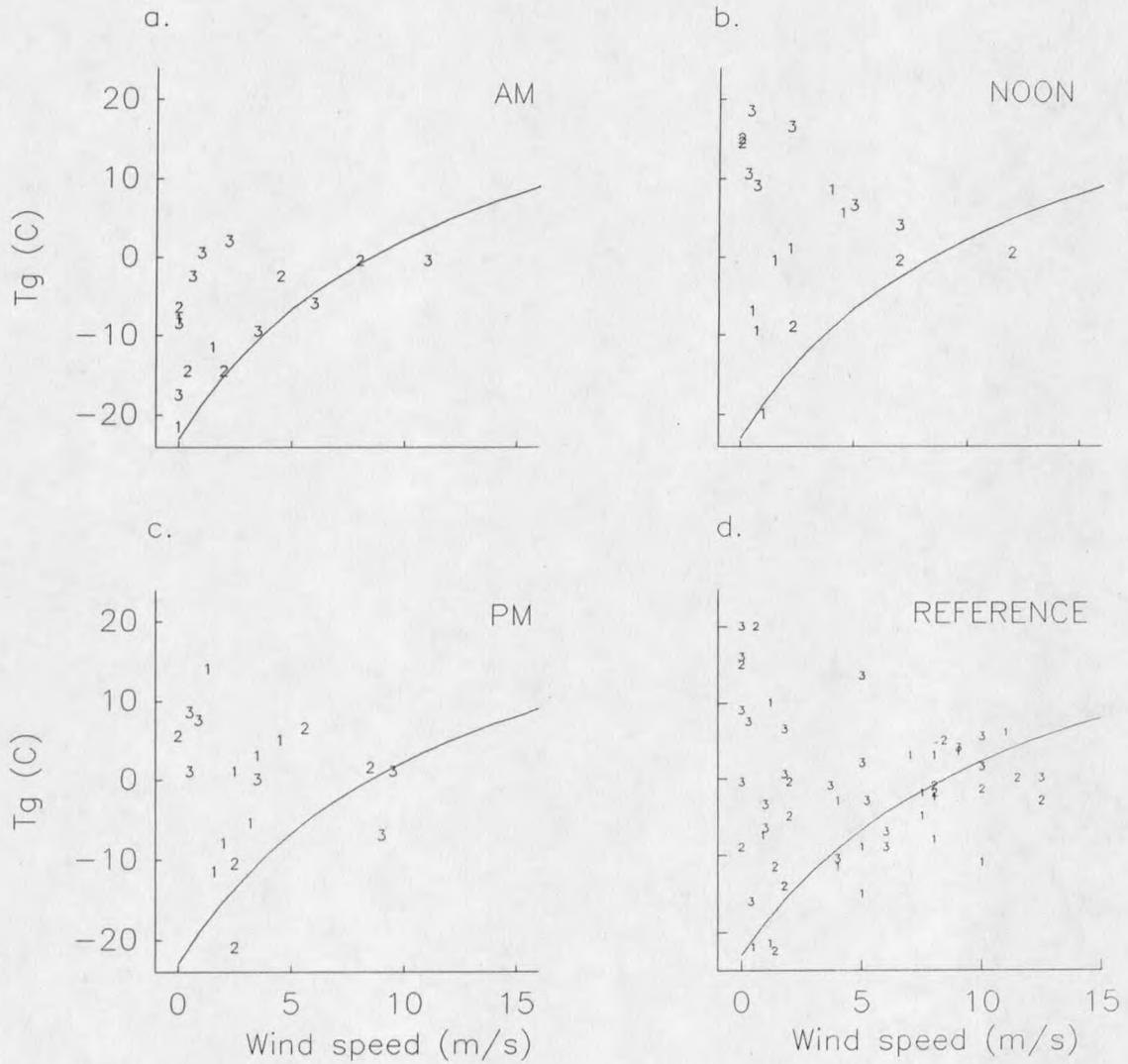
<sup>a</sup>Exposure Index, 3=exposed, 2=moderately protected, 1=protected.

<sup>b</sup> $n=50$  observations, 1 split activity (6 cows).

<sup>c</sup> $n=53$  observations, 15 split activity (11 cow).



**Figure 4.** Black globe temperature ( $T_g$ ) and wind speed at cow location (a) just before sunrise, (b) at noon, and (c) in the afternoon and (d) of reference climate during Winter 1. Curved line represents the lower critical temperature (LCT) for cattle and is equal to  $-23^{\circ}\text{C}$ . Exposure Index: 3 = exposed, 2 = moderately protected, 1 = protected.



**Figure 5.** Black globe temperature ( $T_g$ ) and wind speed at cow location (a) just before sunrise, (b) at noon, and (c) in the afternoon and (d) of reference climate during Winter 2. Curved line represents the lower critical temperature (LCT) for cattle and is equal to  $-23^{\circ}\text{C}$ . Exposure Index: 3=exposed, 2=moderately protected, 1=protected.

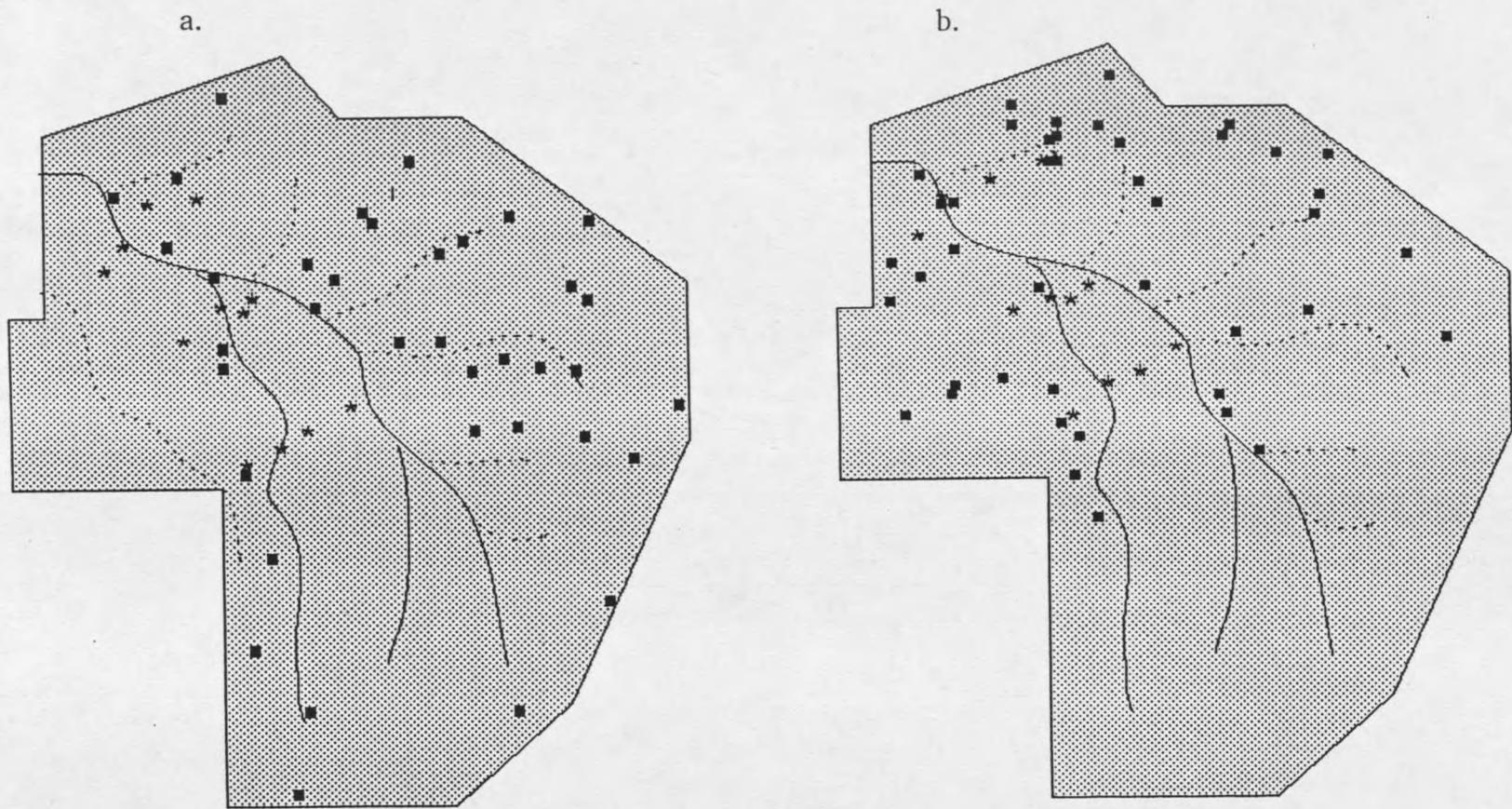


Figure 6. Maps of pasture showing cow locations (■) during (a) Winter 1 and (b) Winter 2. Asterisk (\*) indicates fixed microclimate point.

### Discussion

Cattle selected moderate microclimates for grazing as a response to extreme wind and cold. This may partially explain inconsistent results in studies of daily grazing time (DGT) and organic matter intake (OMI) as a response to cold stress. When cold stressed, cattle rest to conserve energy and may defer grazing until ambient temperatures increase (Malechek and Smith 1976). Cold ambient temperatures have been correlated with a decrease in DGT and OMI (Malechek and Smith 1976, Adams et al. 1986) in relatively open country with little natural or artificial shelter from prevailing winds. Senft and Rittenhouse (1985) predicted that cows would have an effective acclimation period of 9 to 14 days and would reduce forage intake as a response to short term thermal stress (STTS). In contrast, in a pasture adjacent to our study site, DGT was not reduced as a response to STTS (Dunn 1988) with temperature extremes similar to Adams et al. (1986). Prescott (1990) found that DGT, and to a lesser extent OMI, of pregnant cows were affected by fluctuating ambient temperatures in the fall, but were insensitive to the consistently low ambient temperatures during winter.

For free-ranging animals, foraging takes priority over thermoregulatory behavior except under extreme conditions (Ingram and Dauncey 1985). Presumably, in Dunn's (1988) and Prescott's (1990) studies, cows were able to continue grazing in moderate microclimates created by topographic relief, thus

maintaining DGT and OMI.

Microclimates also affected selection of resting sites. Preference for exposed resting sites when conditions were mild, particularly in Winter 1, may have been a response to heat stress. Parker and Robbins (1984) determined that the upper critical temperature (UCT) for mule deer in winter is about 2.5°C. Beall (1974) found that elk preferred daytime bedding sites on north aspects in dense stands of timber when conditions were warm in winter (-4 to 2°C). Under relatively warm winter conditions, higher wind speeds in exposed areas would partially destroy the insulation of the hair coat and increase convective heat loss (Ames and Insley 1975). In contrast, in Winter 2 cows selected protected and moderately protected areas presumably to avoid high wind speeds combined with low temperatures (high windchill). Resting behavior has been correlated to topographic variables that influence microclimate (Senft and Rittenhouse 1985a). They noted that daytime use of south-facing slopes peaked in winter, and observed cattle resting in protected sites on cold windy days. Malechek and Smith (1976) observed cattle standing broadside to the sun on cold, sunny days.

Thermoregulatory behavior of cattle seemed to vary more with regard to windchill than with wind or temperature alone. Cows tended to avoid extreme winds, particularly when temperatures were low. They are probably less sensitive to differences of a few degrees in temperature. Webster (1970) found that pregnant range cows exposed to an ambient temperature of -27°C without wind ( $\mu \leq 0.16 \text{ m s}^{-1}$ ) were not cold stressed, but increased MHP with wind (3.6-5.3 m

s<sup>-1</sup>) at the same temperature. Sakurai and Dohi (1992) observed cows laying down in tight groups when the wind was only 2 to 3 m s<sup>-1</sup> and correlated this with a 2 to 6°C drop in skin temperature compared with skin temperature without wind. Wind of 4.7 km h<sup>-1</sup> (1.3 m s<sup>-1</sup>) at 0°C ambient did not influence metabolic rate (MR) of either bison or cattle, but elevated MR of both at -30°C (Christopherson 1979). On most days in this study, particularly on sunny days, cattle were probably not cold-stressed and could have remained comfortable in any portion of the pasture (Figure 3d and 4d).

Cows tended to graze on the upper slopes of the pasture (exposed) both winters when conditions were mild. This is consistent with the observations of the ranch manager. Periodic strong winds kept ridges and windward-slopes free of snow, making forage more available and travel easier for cattle. Ryder and Irwin (1987) noted that pronghorn preferred windswept ridges for foraging when snow was deep.

The effect of cold stress on cattle grazing native range may be minimized by selecting a pasture which provides natural shelter from extreme wind and cold. Cows may then be able to continue grazing in microclimates where conditions are within their thermoneutral zone. It is possible that cows with previous experience in the pasture will more readily take advantage of these microclimates.

## CHAPTER 4

## SUMMARY

Bluebunch wheatgrass and Idaho fescue were similar in chemical composition within forage type throughout the year. There were differences between species and stage of maturity in disappearance rates and extents. Fall growth was nearly equal in quality and digestibility to April growth, and maintained this quality throughout winter. Although fall growth was not abundant during the study, range management techniques exist to enhance the availability of fall growth when weather conditions are favorable. Standing dead is an important source of roughage providing a high heat increment of feeding, which aids thermoregulation in winter. Successfully matching animal requirements to forage quality throughout the year could help reduce costs, particularly during winter.

Cattle selected moderate microclimates for grazing and resting to avoid high winds and cold temperatures. They also tended to remain in microclimates above the assumed LCT of  $-23^{\circ}\text{C}$ , even though reference climate conditions often were below LCT. The availability of moderate microclimates may allow cows to continue grazing, thus maintaining intake, even when general conditions might otherwise cause them to defer grazing.

In summary, winter range should be considered as habitat for livestock. Management objectives should include providing shelter from prevailing winds

and extreme cold, and to provide adequate forage by enhancing the availability of high protein fall growth when possible while maintaining substantial amounts of standing dead as roughage. Selecting a pasture with diverse topography for winter grazing can help meet these objectives.

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APPENDIX

## WHOLE BODY THERMAL RESISTANCE \*

Whole body thermal resistance in winter ( $r_{Hbs}$ ):

$$r_{Hbs} = 857.9 - 29.9T_e - 0.19T_e^2 + 0.006T_e^3 \text{ (Parker and Robbins 1984)}$$

Thermal resistance of tissue in winter:

$$r_{Ht} = 63.95 - 5.58T_e \text{ (Webster 1974a)}$$

Thermal resistance of coat under low convective conditions ( $\mu < 1 \text{ m s}^{-1}$ ):

$$r_{Hcs} = r_{Hb} - r_{Ht}$$

Whole body thermal resistance to outdoor wind speeds ( $r_{Hb}$ ):

$$r_{Hb} = r_{Ht} + r_{Hc}$$

$$r_{Hc} = r_{Hc} / (1.0 + 0.08\mu) \text{ (Campbell et. al. 1980)}$$

where  $\mu$  was varied from 0 to  $15 \text{ m s}^{-1}$  to represent outdoor wind speeds.  
 $T_e$  was assumed to be equal to  $0^\circ\text{C}$ .

\* adapted from Parker and Gillingham 1990

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