Grazing behavior responses of free-ranging beef cows to fluctuating thermal environments during a winter and a fall season
by Mike L Prescott

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

Abstract:
Two foraging behavior parameters of free-ranging beef cows were examined over a continuous 53d winter season and a continuous 53d fall season. The objective was to examine effects of initial and prolonged exposure to fluctuating and cold ambient temperatures on daily forage intake and time spent grazing. Mean daily temperature (MDT) and short-term thermal stress (STTS) were used to express thermal stressors. Short-term thermal stress was defined as the deviation of the current mean temperature from a running mean temperature of the previous 1 to 20 days. Fecal organic matter output (FO) was estimated for sixteen 6-year-old gestating cows during January and February (Trial 1) and for twelve 7-year-old gestating cows during October and November (Trial 2) using total fecal collections and a Cr_2O_3 dilution technique. Organic matter intake (OMI) as a percentage of body weight (%BW) was calculated from FO and estimates of dietary extrusa IVOMD collected from companion ruminalIy cannulated cows. A reduction ($P<.001$) in OMI as a result of declining MDT was observed in Trials 1 and 2. Short-term thermal stress had a negative linear effect ($P<.05$) on OMI for acclimation lengths of 1 to 14 days during Trial 1. During Trial 2, OMI demonstrated nonlinear responses ($P<.05$) to STTS for acclimation lengths of 2 to 7 days with a tendency for the response ($P<.1$) to be nonlinear for lags of 8 to 10 days. A negative linear response (Pc.001) for lags of 11 to 20 days was observed. The magnitude of response to both MDT and STTS during Trials 1 and 2 was slight. Each of the cows used for determination of OMI was fitted with a vibracorder to monitor grazing time over the same winter (Trial 1) and fall (Trial 2) periods. In Trial 1, there was a positive linear effect ($P<.05$) of MDT on DGT. Positive deviations from acclimated temperatures of 1, 2 and 20 days decreased DGT while negative deviations increased time spent grazing ($P<.05$) . The observed alterations in DGT were small. A nonlinear reduction in mean DGT in response to declining MDT ($P<.001$) and increased STTS ($P<.05$) of up to 194 min was observed in Trial 2. Daily grazing time of free-ranging beef cows appeared to be more responsive to thermal conditions during the fall season than during the winter; however, consistent forage intake was maintained during both initial and prolonged exposure to fluctuating and cold temperatures.

GRAZING BEHAVIOR RESPONSES OF FREE-RANGING BEEF COWS TO FLUCTUATING THERMAL ENVIRONMENTS DURING A WINTER AND A FALL SEASON

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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.

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ABSTRACT

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CHAPTER 1

INTRODUCTION

The fluctuating thermal environment common to southwestern Montana rangelands may be a primary stressor of free-ranging beef cows. Ewbank (1985) reported that departures from normal behavioral patterns, such as foraging behavior, in response to novel or unfamiliar environmental characteristics may indicate animal stress. Environmental stressors which affect the foraging behavior of grazing livestock could potentially impact the nutritional status of those animals. Biological consequences for the animals may be classified as physiological stress (harmless), overstress (some damage) or distress (pathological) (Ewbank, 1985).

Free-ranging conditions may increase the energy requirements of cattle by 25 to 50% over confinement conditions (Osuji, 1974); however, nutrient demands can be met if the grazing ruminant can ingest sufficient quantities of low-quality forage (Allison, 1985). According to Arnold and Dudzinski (1978), daily intake of range forage is determined by the amount of time spent grazing and the rate of harvest.

Senft and Rittenhouse (1985) developed a hypothetical model stating that grazing activity is minimized in response to short-term deviations of the current thermal conditions from the animal's acclimated state. Adams et al., (1986) proposed that daily grazing time and forage intake of beef cows grazing winter range are reduced as minimum daily temperature declines. Recent examinations of foraging behaviors of range beef cows during winter demonstrated consistency and insensitivity to short-term thermal stress despite fluctuating and cold temperatures (Dunn et al., 1988; Beverlin et al., 1989).

Beverlin et al. (1989) suggested that the model of Senft and Rittenhouse (1985) and the hypothesis of Adams et al. (1986) may be appropriate during transitional periods when grazing cattle are acclimating to seasonal changes in the thermal environment, but may not apply to the consistently cold temperatures of winter. The fall and winter periods are characterized by initial and prolonged stages of exposure, respectively, to fluctuating and declining ambient temperatures. Our objective was to examine forage intake and daily grazing time of free-ranging prepartum beef cows during a winter and a fall season in response to mean daily temperature and short-term thermal stress.

CHAPTER 2

ORGANIC MATTER INTAKE OF FREE-RANGING BEEF COWS DURING A FALL AND A WINTER SEASON

Materials and Methods

Trial 1

The study area was a 324 ha native range pasture located on the Red Bluff Research Ranch (latitude 45° 35'N; longitude 111° 34'W), Norris, Montana. The pasture contained sandy and silty range sites typical of southwestern Montana foothill range. Dominant vegetation included bluebunch wheatgrass (*Agropyron spicatum*), needleandthread (*Stipa comata*), Idaho fescue (*Festuca idahoensis*) and basin wildrye (*Elymus cinereus*). Elevation ranged from 1400 to 1900 m. The prevailing southwesterly wind and naturally protected microclimates maintained accessible forage throughout the study.

Sixteen (n=16) pregnant Hereford X Angus and Tarentaise X Angus cows were selected from the Red Bluff Ranch herd. All cows were six years old, had similar previous grazing experiences and were in the last trimester of gestation during the study. Initial and final mean body weights (kg) and condition scores (visual and palpable scale of 1=thin-10=fat; LaMontagne, 1981) were 574$\pm$11.8 (SE), 563$\pm$10.9kg, 5.5$\pm$0.1 and

4.2±0.2, respectively. The cows grazed in the study area for a two-week adjustment period, beginning December 18, 1987, prior to data collection. A loose iodized salt mixture containing 30% dicalcium phosphate and 30% potassium chloride was provided ad libitum. No other supplemental feeds were provided throughout the study.

Fecal organic matter output (FO) was estimated by a Cr_2O_3 dilution technique (Raleigh et al., 1980) based on daily rectal grab samples and total fecal collections. Each cow was bolused daily at 1130h with 10g Cr_2O_3 in a gelatin capsule (size No. 10) and rectal fecal grab samples were collected for Cr_2O_3 analysis. Prior experimentation (Dunn, 1986) indicated that 1100 to 1330h was a regular non-grazing period. The marker was administered for 6 days before sampling began to establish steady state conditions (Pond et al., 1987). Total fecal collections (96h) were obtained from four groups of four cows. Two collections were made on each group during the study, one in January and one in February. Fecal bags were changed daily during collection periods at time of bolusing.

Rectal grab samples were immediately frozen after collection. Total collected feces were weighed, mixed, subsampled and frozen. Dry matter and organic matter of each fecal sample was determined following AOAC (1980) procedures. The remaining fecal material was dried at 100 C for not less than 3 days and ground through a 2mm screen in a Wiley mill. Spectrophotometry was used to determine Cr_2O_3 concentration in each sample following procedures adapted from Fenton and Fenton (1979) and Costigan and Ellis (1986). Beverlin (1988) provides a complete description of the analysis. Rectal grab samples were adjusted individually for each cow based on total fecal collections to account for percent Cr_2O_3 recovery and diurnal variation in excretion patterns. Fecal output per day was estimated from rectal grab samples based on the following equation:

FO (g per day) = [Cr_2O_3 (g fed per day)]/[Cr_2O_3 (% in dry fecal sample)] (1)

Four rumen cannulated cows grazed concurrently in the study pasture and extrusa samples were collected weekly from these animals using a total evacuation technique (Lesperance et al., 1960). Two of the cows were penned overnight without feed or water. Rumen contents were removed the following morning, the inside of the rumen rinsed with water and the excess removed. Animals were allowed to graze freely for 1 to 1.5 h after which the ingesta was removed, mixed, subsampled and frozen. Initial rumen contents were returned to the rumen and the animals were released. The procedure was repeated on the other two cows the following day. Each sample was freeze dried and ground through a 1mm screen using a Wiley mill. In vitro organic matter digestibility (IVOMD) of the diet was determined using the Barnes modification of the Tilley and Terry technique (Harris, 1970).

Forage organic matter intake (OMI) was estimated using the following equation:

$$OMI = [daily\ FO\ (kg)]/[1-IVOMD] \quad (2)$$

Ambient air temperature was measured continuously at the research ranch using a meteorograph. Components of a model developed by Senft and Rittenhouse (1985) were used to express the effect of the ambient air temperature of the previous 1 to 20 days on OMI. Mean daily temperature (MDT) was calculated for the period 0701 to 0700h for the present day (i), to coincide with the period during which OMI was being estimated. Mean daily temperature is the weighted mean of daily maximum temperature [$T_{max}(i)$], daily minimum temperature [$T_{min}(i)$] and minimum temperature for the following day [$T_{min}(i+1)$]:

$$MDT=[2(T_{max}(i))+(T_{min}(i))+(T_{min}(i+1))]/4 \quad (3)$$

Running mean temperatures [$T_{accl}(L)$] represent the time course of thermal acclimation and were calculated using mean daily temperatures for the 1 to 20 days [(L) = 1-20 days] previous to the present day (i):

$$T_{accl}(L)=[(\text{sum of L days for } j=1-L)(T_{(i-j)})]/L \quad (4)$$

Short-term thermal stress (STTS) was defined as the deviation of MDT from the hypothetical acclimated temperature $T_{accl}(i)$:

$$STTS=MDT-T_{accl}(i) \quad (5)$$

Mean daily temperature ranged from 7.75 to -13.00 C with a mean of -2.29$\pm$.19 C during the study. Acclimated temperatures calculated as running mean temperatures for 6 and 12 days previous to day (i) (6 and 12d lags) along with MDT are shown in Figure 1.

Statistical Analysis System's Regression analysis (SAS, 1988) was used to determine the effect of MDT and STTS on OMI. Independent variables included in the polynomial stepwise regression were the linear, quadratic and cubic terms for MDT and STTS and interactions of these variables. Organic matter intake was the dependent variable. Presence (1) or absence

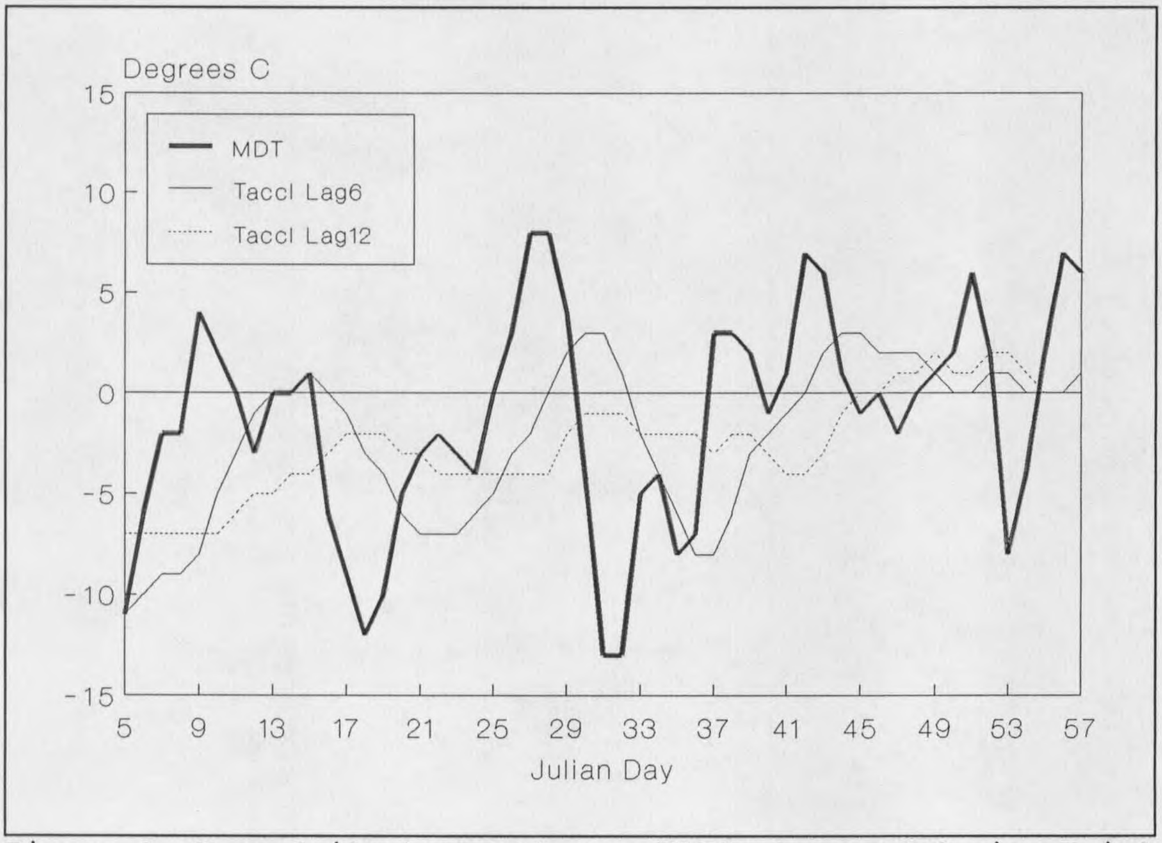

Figure 1. Mean daily temperatures (MDT) observed during Trial 1. Acclimated temperatures (T_{accl}) for 6 and 12 day lags illustrate the difference in acclimation lengths. Short-term thermal stress (STTS) is the deviation of MDT from T_{accl}.

(0) of a fecal bag was included as an indicator variable in the model. Significance level for entry or removal of the parameters from the model was set at $p<.05$. Dietary IVOMD was tested for differences between weekly means using regression analysis (SAS, 1988).

Trial 2

The study site for Trial 2 was the same as described in Trial 1. Twelve (n=12) gestating Hereford X Angus and Tarentaise X Angus were selected from the ranch herd to be used as the study animals. All cows were seven years old and had similar previous grazing experiences at the study site. Initial and final weights and condition scores (1=thin-10=fat) were determined as in Trial 1 and were 597 ± 10.9, 602 ± 10.9kg, 5.8 ± 0.1 and 6.0 ± 0.3, respectively. Olson-Rutz (personal communication, 1988) reported that a minimum sample size of 9 cows was required to establish confidence intervals at an alpha level of .05 for estimation of FO. Therefore animal numbers were reduced from Trial 1. Range forage was readily accessible throughout the study. A salt mix was provided ad libitum and no other supplemental feeds were made available.

Fecal output, IVOMD and OMI were estimated over a continuous 53d period following the same procedures as outlined in Trial 1, with the exception that procedures for estimating dry matter and organic matter (AOAC, 1980) of fecal samples were completed and samples dried the same day as collection.

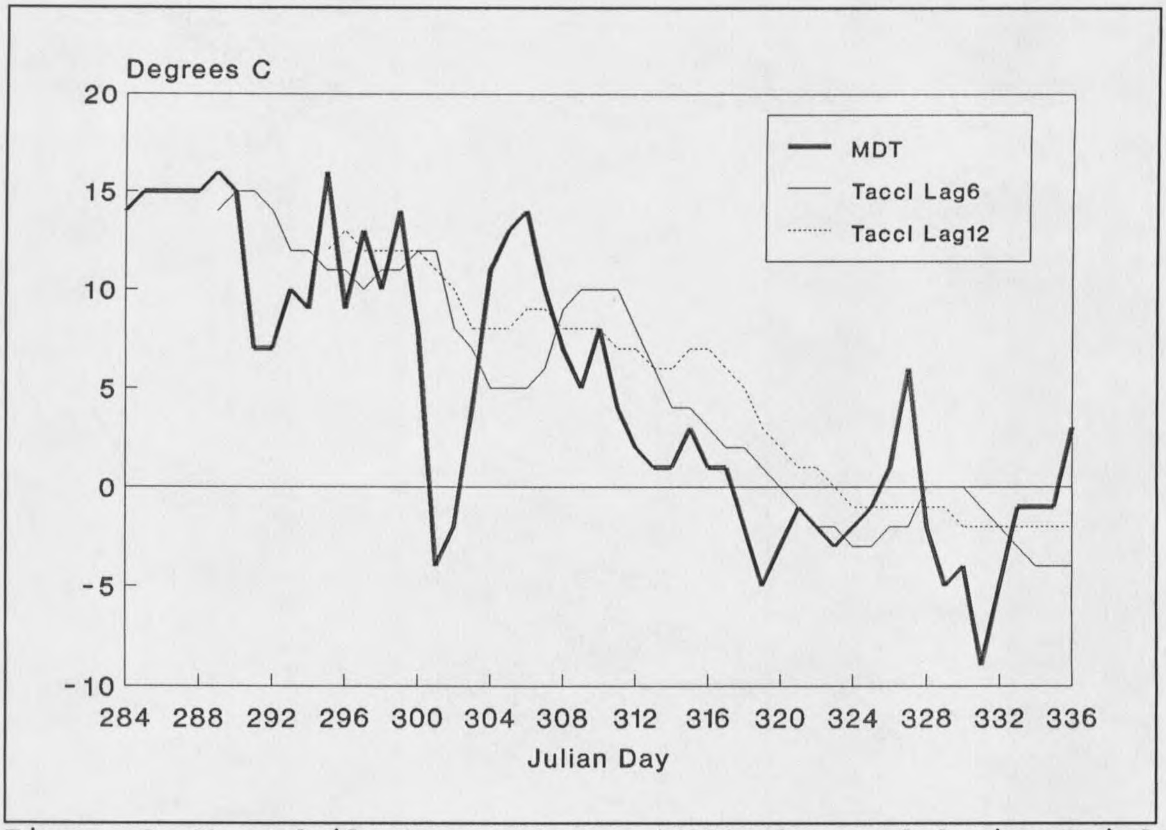

Figure 2. Mean daily temperatures (MDT) observed during Trial 2. Acclimated temperatures (T_{accl}) for lags of 6 and 12 days illustrate the difference in acclimation lengths. Short-term thermal stress (STTS) is the deviation of MDT from T_{accl}.

The components of the Senft and Rittenhouse (1985) model were similar to those described in Trial 1 with the exception of MDT. Mean daily temperature for the period 0701 to 0700 was calculated from mean hourly ambient temperatures recorded at the research ranch rather than as a weighted mean of minimum and maximum ambient temperatures. This approach may give a more realistic picture of the thermal environment by including the relative duration of warm or cold temperatures within a day rather than only minimum and maximum observed temperatures. Mean daily temperature during Trial 2 and T_{accl}

for lags of 6 and 12 days are presented in Figure 2. Mean daily temperature ranged from 16.33 to -9.27 C with a mean of 4.72±.28 C. Statistical analysis followed the same procedures outlined in Trial 1.

Results and Discussion

Trial 1

The average for diet IVOMD was 27.86±.42% and did not change significantly (P>0.05) during the trial. Since diet digestibility remained constant during the 60d study, any variation in foraging behavior due to changes in forage quality would be minimal. Behavioral responses to forage dynamics have been reported (Leaver, 1985). Weekly IVOMD means (Appendix Table 5) are similar to values reported by others for diets of dormant winter forage (Turner, 1985; Dunn, 1986; Beverlin et al., 1989). Mean FO (0.79±.004%BW) is comparable to results obtained by others for beef cows grazing Montana foothill ranges (Turner, 1985; Dunn, 1986; Beverlin et al., 1989). Organic matter intake as a percentage of BW averaged 1.09±.005 throughout the study. This value is similar to OMI (0.92%BW) for unsupplemented cows grazing the same area the previous winter (Beverlin, 1988). Mean FO and OMI for each cow during Trial 1 are given in Appendix Table 7.

Polynomial regression did not significantly improve the fit of the regression equations. The final model included

Table 1. Responses of organic matter intake (OMI) to mean daily temperature (MDT) and short-term thermal stress (STTS) for acclimation lengths (LAG) of 1 to 20 days (Trial 1).[ab]

	Parameter	
LAG	MDT	STTS
1	.006[d]	-.005[d]
2	.006[d]	-.005[d]
3	.007[d]	-.004[d]
4	.007[d]	-.004[c]
5	.007[d]	-.003[c]
6	.007[d]	-.003[c]
7	.008[d]	-.004[c]
8	.009[d]	-.005[d]
9	.011[d]	-.007[d]
10	.012[d]	-.007[d]
11	.012[d]	-.008[d]
12	.012[d]	-.008[d]
13	.011[d]	-.008[d]
14	.009[d]	-.006[c]
15		
16		
17		
18		
19		
20		

[a]Model for each lag (1-14) significant ($P<.001$).
[b]Magnitude of response is OMI as percentage body weight per degree C and degree STTS.
[c]$P<.05$, [d]$P<.001$.

linear terms of MDT, STTS and fecal bag, as independent variables with OMI as the dependent variable. One cow was not pregnant and was not included in the analysis. Effects of MDT and STTS on OMI for acclimation lengths of 1 to 20 days are given in Table 1. Mean daily temperature had a positive linear effect on OMI for acclimated temperatures calculated for lags of 1 to 14 days ($P<.001$) and was associated with a slight reduction in OMI at colder temperatures. Organic matter intake demonstrated small negative responses to STTS for lags of 1 to 14 days ($P<.05$). Thus OMI increased slightly at negative STTS values. The largest positive and negative STTS values observed were 12.45 and -16.50 C, respectively. No other acclimation lengths were significant. The model for an acclimation length of 10 days provided the best fit to the data (Adj R-sq = 0.05) and may best describe the response of OMI to MDT and STTS observed during Trial 1 (Figure 3). Caution must be used in interpreting the response surfaces presented due to the lack of data points at the extremes.

These results initially appear to agree with the hypotheses that OMI is reduced as a result of exposure to cold temperatures (Adams et al., 1986) and deviations of the current thermal conditions from the animals' acclimated state (Senft and Rittenhouse, 1985). However, the regression equation predicted OMI at the maximum positive and negative MDT (7.75, -13.00) and STTS values (12.45, -16.50) observed during Trial 1 to be 1.11%BW and 1.09%BW, respectively. The result is an increase in OMI of .02%BW over the mean OMI at high MDT and positive STTS, and no change in OMI at low MDT and negative STTS. Thus, the minimal response of OMI to MDT and STTS indicates that gestating range cows maintain relatively consistent forage intake when exposed to fluctuating and cold temperatures characteristic of the winter season. The small alterations in OMI may be of no biological