



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
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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 Cr₂O₃ 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 ruminally 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 ($P < .001$) 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

by

Mike L Prescott

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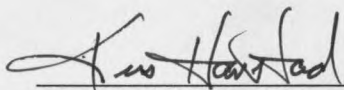
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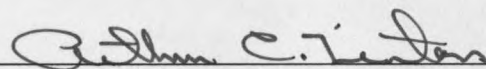
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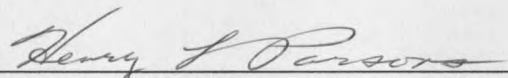
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ABSTRACT

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 ruminally 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 ($P<.001$) 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.

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 SEASONMaterials and MethodsTrial 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±11.8 (SE), 563±10.9kg, 5.5±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:

$$\text{FO (g per day)} = [\text{Cr}_2\text{O}_3 \text{ (g fed per day)}] / [\text{Cr}_2\text{O}_3 \text{ (\% in dry fecal sample)}] \quad (1)$$

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:

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

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 $[T_{\min}(i+1)]$:

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

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

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

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

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

Mean daily temperature ranged from 7.75 to -13.00 C with a mean of -2.29 ± 1.19 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

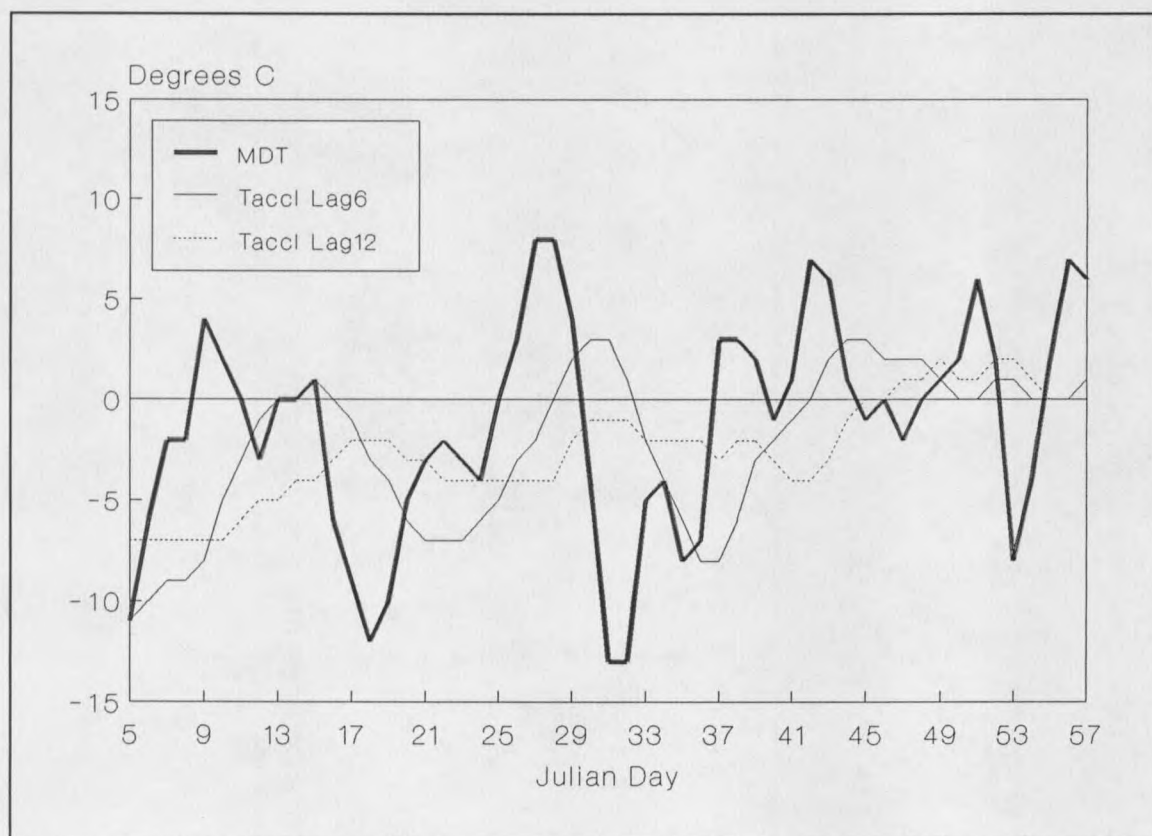


Figure 1. Mean daily temperatures (MDT) observed during Trial 1. Acclimated temperatures (T_{accl}) for 6 and 12 day lags illustrate the difference in acclimation lengths. Short-term thermal stress (STTS) is the deviation of MDT from T_{accl} .

(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 ± 10.9 kg, 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.

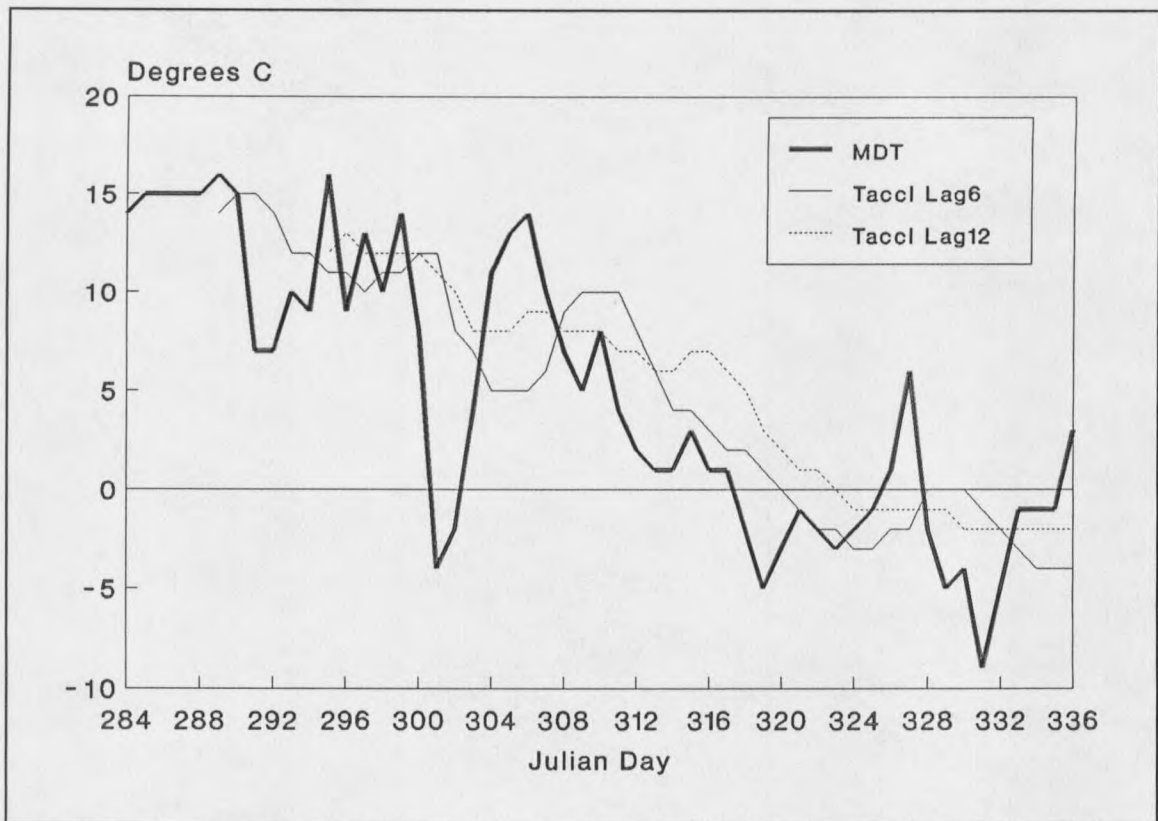


Figure 2. Mean daily temperatures (MDT) observed during Trial 2. Acclimated temperatures (T_{accl}) for lags of 6 and 12 days illustrate the difference in acclimation lengths. Short-term thermal stress (STTS) is the deviation of MDT from T_{accl} .

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 $4.72 \pm .28$ C. Statistical analysis followed the same procedures outlined in Trial 1.

Results and Discussion

Trial 1

The average for diet IVOMD was $27.86 \pm .42\%$ 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 ($0.79 \pm .004\%$ 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 $1.09 \pm .005$ 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}

LAG	Parameter	
	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		

^aModel for each lag (1-14) significant ($P < .001$).

^bMagnitude 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

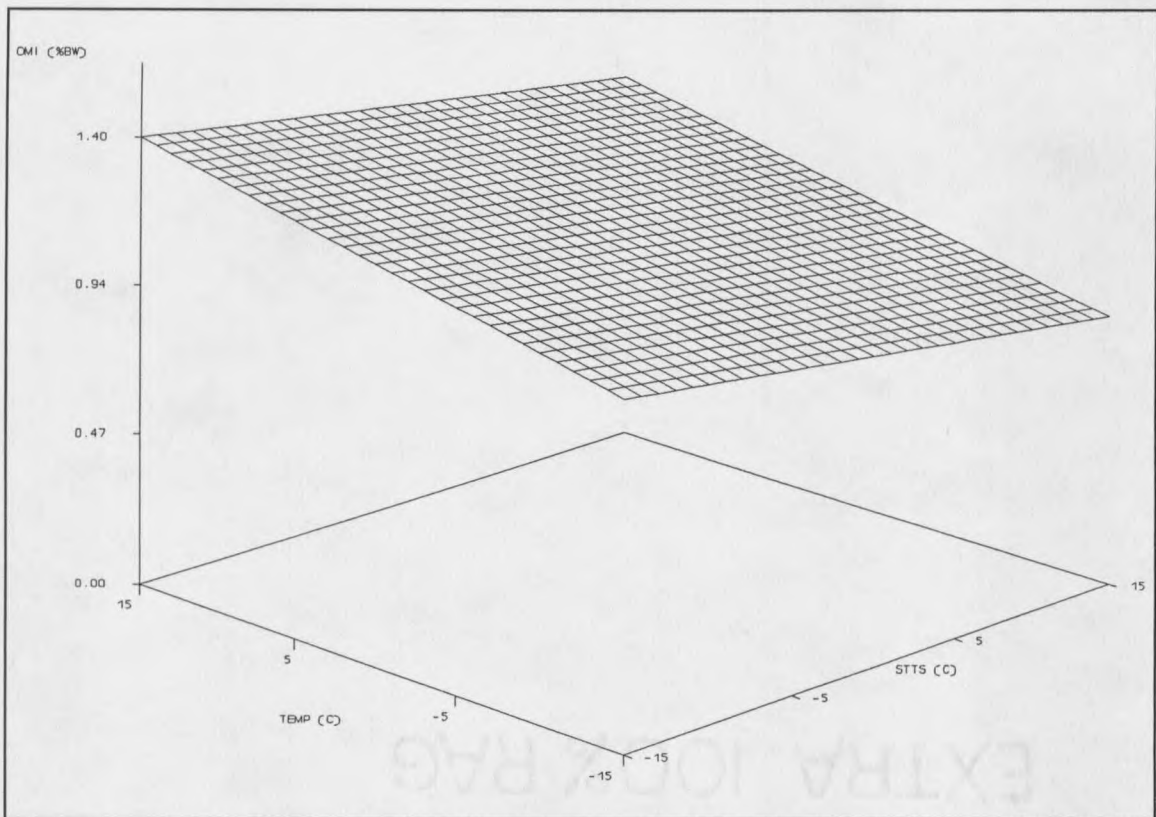


Figure 3. Effect of mean daily temperature (MDT) and short-term thermal stress (STTS) on organic matter intake (OMI) during Trial 1. $OMI = 1.12 + .012(MDT) - .007(STTS)$.

significance to the animals. Beverlin et al. (1989) also observed minimal behavioral responses of free-ranging cows to alterations in the winter thermal environment.

Senft and Rittenhouse (1985) reported an acclimation lag of 9 to 14 days for cattle throughout a year. This conclusion was based on the acclimation lags which provided the best fit to the data. Due to the small and similar amount of variation accounted for by the acclimation lengths during this trial, a singular acclimation length which represents the time course of thermal acclimation was not determined.

The presence of fecal bags reduced OMI ($P < .05$) by an

average of 0.033%BW over acclimated temperatures for 1 to 14 days. The regression equation from the best fit model (10d lag) indicates that at the maximum positive and negative MDT and STTS values observed during Trial 1, fecal bags reduced OMI by .01%BW and .027%BW, respectively, from the mean OMI of 1.09%BW. Therefore, the influence of fecal bags used for total fecal collections is interpreted as having little impact on OMI.

Trial 2

In vitro organic matter digestibility of rumen extrusa samples collected weekly during Trial 2 averaged $33.78 \pm .68$ and declined slightly (-0.89% ; $P < .05$). The decrease in diet IVOMD was considered to have minimal influence on the grazing behavior of the study animals, given the slight magnitude of the decline. Cook and Harris (1968) indicated that a decline in digestibility of cool season graminoids associated with approaching winter dormancy may be expected in the fall. Weekly IVOMD means are reported in Appendix Table 6. Mean FO ($0.72 \pm .004\%$ BW) is slightly less than FO observed in Trial 1. This difference is attributed to the higher digestibility of diets selected during the present trial compared to Trial 1. Mean OMI was $1.09 \pm .006\%$ BW throughout the trial and is comparable to OMI observed during the previous winter (Trial 1). Mean FO and OMI for each cow during Trial 2 are reported in Appendix Table 8.

Table 2. 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 2).^{ab}

LAG	Parameter		
	MDT	STTS	STTS ²
1	.007 ^e	-.003 ^c	
2	.008 ^e	-.003 ^d	.0006 ^e
3	.009 ^e	-.004 ^d	.0007 ^e
4	.009 ^e	-.005 ^e	.0006 ^e
5	.010 ^e	-.005 ^e	.0005 ^d
6	.011 ^e	-.006 ^e	.0004 ^d
7	.011 ^e	-.006 ^e	.0003 ^d
8	.012 ^e	-.007 ^e	.0003 ^c
9	.012 ^e	-.007 ^e	.0003 ^c
10	.012 ^e	-.008 ^e	.0004 ^c
11	.013 ^e	-.009 ^e	
12	.013 ^e	-.009 ^e	
13	.014 ^e	-.009 ^e	
14	.015 ^e	-.009 ^e	
15	.015 ^e	-.010 ^e	
16	.015 ^e	-.010 ^e	
17	.016 ^e	-.011 ^e	
18	.017 ^e	-.012 ^e	
19	.017 ^e	-.014 ^e	
20	.017 ^e	-.015 ^e	

^aModel for each lag (1-20) significant ($P < .001$).

^bMagnitude of response is OMI as percentage body weight per degree C and degree STTS.

^c $P < .1$, ^d $P < .05$, ^e $P < .001$.

Stepwise regression analysis indicated that the final model should include MDT, linear and quadratic terms for STTS, and fecal bag as independent variables. Organic matter intake exhibited a slight positive response ($P < .001$) to MDT for acclimation lengths of 1 to 20 days (Table 2) indicating a small decrease in OMI at colder temperatures. Short-term

thermal stress resulted in a slight reduction in OMI for acclimation lengths of 1 to 20 days. There was a significant quadratic response ($P < .05$) to STTS for lags of 2 to 7 days with a tendency ($P < .1$) for OMI to respond nonlinearly to deviations from acclimated temperatures calculated for 8, 9 and 10 day lags. The response of OMI to STTS was linear for acclimation lengths of 11 to 20 days ($P < .001$) (Table 2).

The maximum positive and negative STTS values observed during Trial 2 were 12.13 and -15.97 C, respectively. The model which accounted for the most variation in OMI (13d lag; Adj R-sq=0.21) was used to define the response surface describing the effects of MDT and STTS on OMI during Trial 2 (Figure 4). This regression equation indicates that the maximum positive and negative temperatures (16.33, -9.27) and STTS values (12.13, -15.97) observed during the study resulted in an increase of .06 OMI%BW and a decrease of .05 OMI%BW, respectively, from mean OMI of 1.09%BW. The biological significance of the responses observed during Trial 2 appears to be minimal. Thus, free-ranging beef cows maintain relatively consistent forage intake during the initial stages of exposure to fluctuating and cold temperatures characteristic of the fall season.

Fecal bags used for total fecal collections reduced OMI ($P < .05$) by an average of 0.036%BW over acclimated temperatures for 1 to 16 days. The regression equation of the best fit model (13d lag) indicates that fecal bags would reduce OMI by

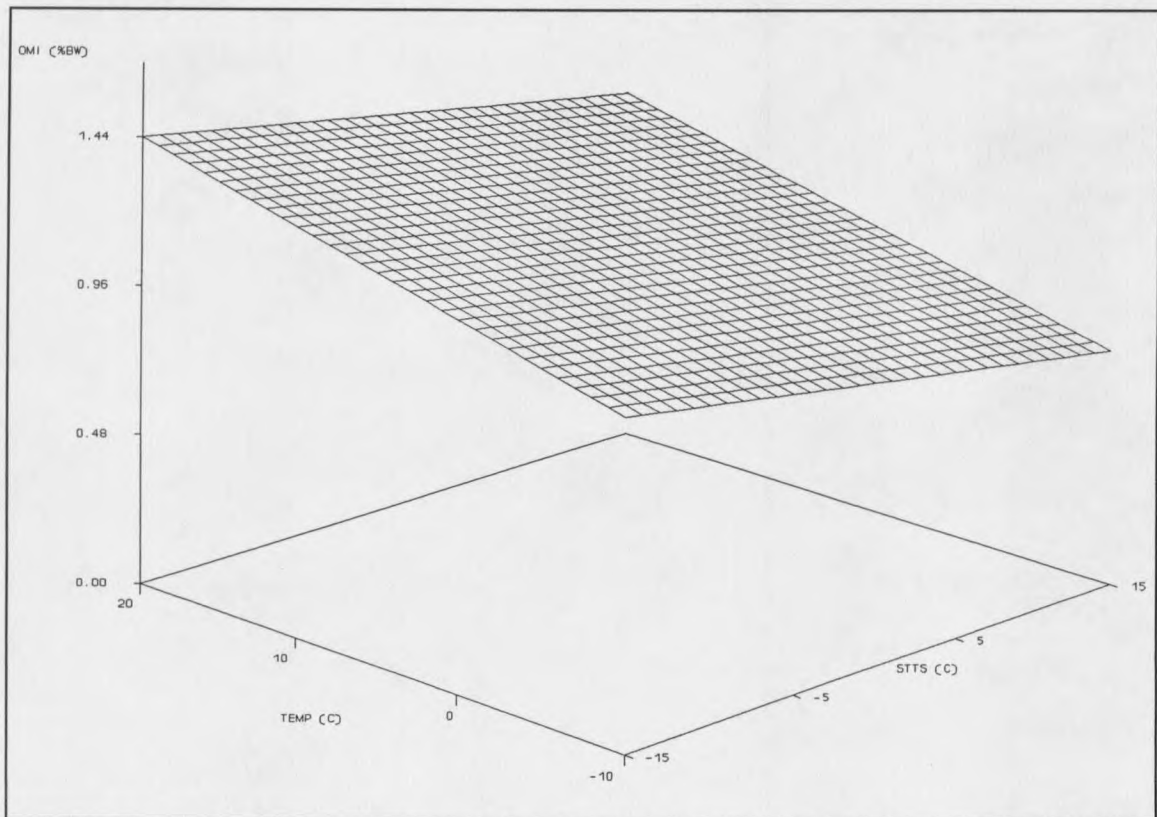


Figure 4. Effect of mean daily temperature (MDT) and short-term thermal stress (STTS) on organic matter intake (OMI) during Trial 2. $OMI = 1.03 + .014(MDT) - .009(STTS)$.

0.08%BW at the maximum negative observed values for MDT and STTS. An increase in OMI of 0.02%BW over mean OMI was predicted at maximum positive MDT and STTS observed during Trial 2 when animals were used for total fecal collections. Therefore, presence of fecal bags was interpreted as having little influence on OMI.

The consistent intake of range forage by free-roaming beef cows exhibited during Trial 1 may be an indication that exposure to thermal stressors during mid-winter is not novel to the animals. Physiological acclimation, resulting in an increased resting metabolism and downward shift in the

thermoneutral zone, has been reported for beef cows exposed to naturally occurring cold winter conditions (Young, 1975). The thermal regimes encountered by acclimated animals within familiar winter environments may be within their thermoneutral zone. Ingram and Dauncey (1985) indicated that obtaining food is of highest priority under free-ranging conditions and takes precedence over other forms of thermoregulatory behavior except under the most severe climatic conditions. The minimal alterations in OMI to thermal stress observed during Trial 2 do not support the hypothesis that forage intake of free-ranging cows is more responsive to thermal stressors during fall transitional periods than prolonged cold exposure associated with the winter season. Beverlin et al. (1989) suggested that for winter foraging patterns, consistency of forage intake may represent a minimizing of collective behaviors and daily energy expenditures within familiar environments. This hypothesis may also apply to transitional periods, such as the fall as animals are becoming physiologically acclimated to declining ambient temperatures. Rates and duration of forage harvest may be altered when grazing beef cows are initially exposed to declining fall ambient temperatures prior to completion of physiological and behavioral acclimation. It is also possible as Dunn et al. (1988) suggested that previous grazing experiences in an environment mitigate certain behavioral responses to thermal stressors during both familiar and transitional periods.

CHAPTER 3

DAILY GRAZING TIME OF FREE-RANGING BEEF COWS
DURING A FALL AND A WINTER SEASONMaterials and MethodsTrial 1

This study was conducted over a continuous 53d period from January 5 to February 27, 1988, in a 324 ha native range pasture at the Red Bluff Research Ranch, Norris, MT. A description of the study site is reported in Chapter 2.

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 condition scores and weights of the study animals are given in Chapter 2, Trial 1. The cows grazed in the study area beginning December 18, 1987, for a two-week adjustment period 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.

Each of the sixteen cows was fitted with an 8d vibracorder to record grazing events (Stobbs, 1970) over 53

continuous days. Daily grazing time was estimated to the nearest 15 min for the period 0701-0700h. Each animal wore the same vibracorder throughout the trial and charts were changed weekly at 1130h. Prior experimentation (Dunn et al., 1988) indicated that 1130h was a non-grazing period for beef cows in the winter.

Ambient air temperature was measured continuously at the research ranch using a meteorograph. Mean daily temperature ranged from a high of 7.75 to a low of -13.00 C with a mean of $-2.29 \pm .19$ C during the study. Components of a model developed by Senft and Rittenhouse (1985) were used to express the effect of ambient air temperature of the previous 1 to 20 days on DGT. A complete description of the model components and climatic conditions during the study period is given in Chapter 2.

Statistical Analysis System's Regression analysis (SAS, 1988) was used to examine the effect of MDT and STTS on DGT. Independent variables included in the polynomial stepwise regression were the linear, quadratic and cubic terms for MDT and STTS and interactions of these variables. The study animals wore fecal bags for two 96h collection periods for estimation of organic matter intake during a consecutive study (Chapter 2). Since Beverlin (1988) reported a decline in DGT due to total fecal collections, presence (1) or absence (0) of a fecal bag was included as an indicator variable in the model. The variation in DGT due to fecal bags was partitioned

out in the analysis so as not to confound the parameter estimates of MDT and STTS. Significance level for entry or removal of the parameters from the model was set at $p < .05$.

Trial 2

This study was conducted from October 11 to December 2, 1988, at the Red Bluff Research Ranch, Norris, MT. A description of the 324 ha study site is given in Chapter 2. Daily grazing time was estimated for twelve ($n=12$) gestating six year old Hereford X Angus and Tarentaise X Angus cows over a continuous 53d period. Each cow was fitted with a 24h vibracorder to record daily grazing activity. Daily grazing time was estimated to the nearest 5 min for the period 0701 to 0700h. Cows wore the same vibracorder throughout the trial and charts were changed daily at 1130h. All cows had similar previous grazing experiences and were moved to the study pasture on September 21, 1988, prior to data collection. As in Trial 1, native range forage was readily accessible throughout the study and animals were provided the same salt mix (ad libitum); no other supplemental feeds were made available. Initial and final condition scores and weights of the study animals are reported in Chapter 2, Trial 2.

The components of the Senft and Rittenhouse (1985) model used to quantify STTS were similar to those described in Chapter 2. Mean daily temperature was calculated as the average of mean hourly ambient temperatures for Trial 2. The

range of MDT was from 16.33 to -9.27 C with a mean of $4.72 \pm .28$ C. Mean daily temperatures for each day of the study are reported in Chapter 2, Trial 2. Data were analyzed by the same statistical procedures outlined in Trial 1.

Results and Discussion

Trial 1

Mean DGT observed in Trial 1 (513 ± 2.6 min/day) was similar to reported winter grazing times (528 min/day, Dunn et al., 1988 and 510 min/day, Beverlin et al., 1989) of prepartum cows at the same study site.

The stepwise analysis indicated that polynomial regression did not significantly improve the fit of the regression equations. The final model included linear terms of MDT, STTS and fecal bag as independent variables with DGT as the dependent variable. One cow was not pregnant and was not included in the analysis. Daily grazing time demonstrated a positive response to MDT ($P < .05$) for acclimated temperatures calculated over 1, 2, 14, 16, 17 and 20 days (Table 3). Short-term thermal stress had a negative effect on DGT ($P < .05$) for acclimation lags of 1, 2, and 20 days (Table 3). The magnitude of response to both parameters was minimal. The largest positive and negative STTS values observed were 12.45 and -16.50 C, respectively. No other acclimation lengths were significant.

The minimal and inconsistent response of DGT to MDT and

STTS over the range of observed acclimated temperatures indicates that free-ranging beef cows maintain consistent grazing behavior within a familiar winter environment. To illustrate, the best fit regression equation (2d lag, Adj R-sq=0.08) predicted DGT to be 517 min at the maximum positive MDT (7.75) and STTS (12.45) observed during the study and 532 min at maximum negative MDT (-13.00) and STTS (-16.50). The

Table 3. Responses of daily grazing time (DGT) to mean daily temperature (MDT) and short-term thermal stress (STTS) for acclimation lengths (LAG) of 1 to 20 days (Trial 1).^{ab}

LAG	Parameter	
	MDT	STTS
1	1.05 ^c	-1.78 ^c
2	1.26 ^c	-1.42 ^c
3		
4		
5		
6		
7		
8		
9		
10		
11		
13		
14		
15	2.62 ^c	
16	2.54 ^d	
17	3.03 ^c	
18	3.16 ^c	
19		
20	4.21 ^c	-3.74 ^c

^aModel for each lag (1-20) significant (P<.001).

^bMagnitude of response is min per degree C and degree STTS.

^cP<.05, ^dP=.07.

greatest increase in DGT is only 19 min over mean DGT. The response surface defined by the parameter estimates for MDT and STTS calculated for a 2d lag illustrates the consistency of DGT during the winter (Figure 5).

Dunn et al. (1988) and Beverlin et al. (1989) also reported that cows grazing winter range exhibited minimal behavioral responses to cold exposure. In contrast to the present study, Adams et al. (1986) found that six year old cows grazed an average of 446 min/day during mid-winter and 432 min/day in during the late fall and early winter. These

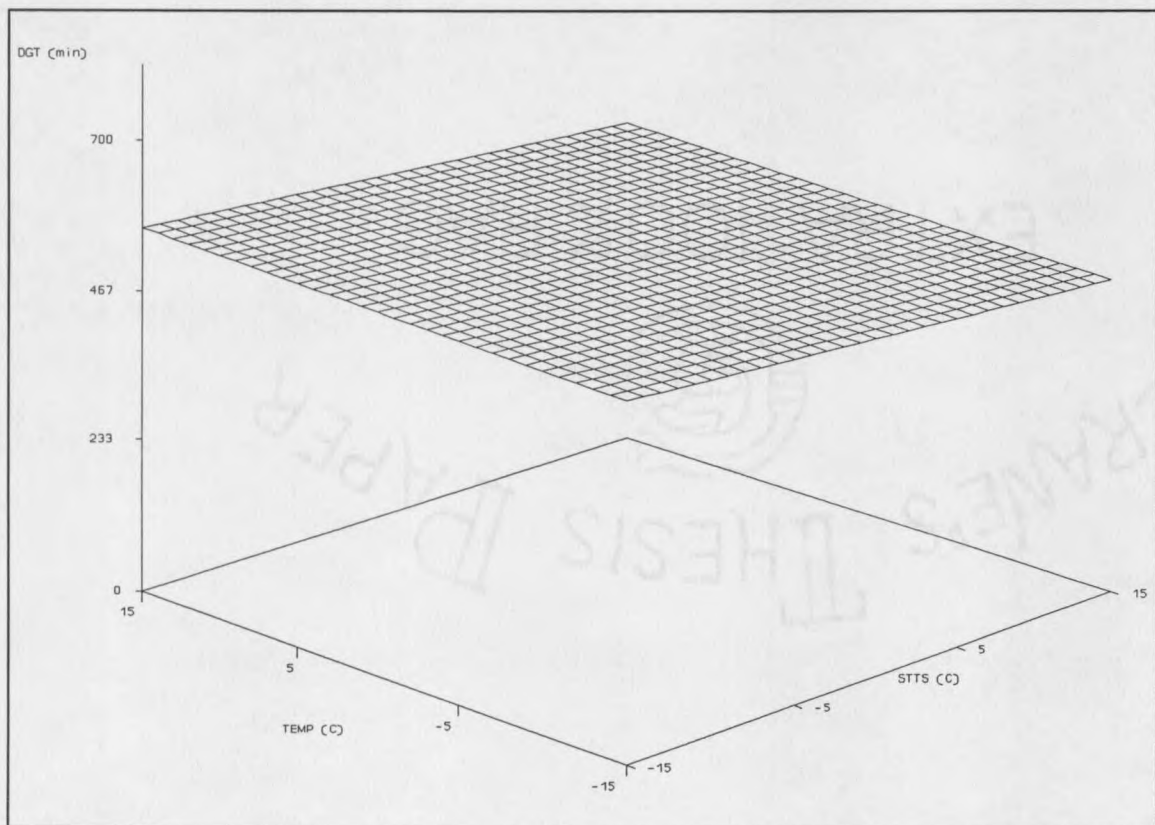


Figure 5. Effect of mean daily temperature (MDT) and short-term thermal stress (STTS) on daily grazing time (DGT) during Trial 1. $DGT = 525.08 + 1.26(MDT) - 1.42(STTS)$.

investigators also reported that total daily grazing time decreased linearly as minimum daily temperature declined. The differences between winter studies may be due to differences in structural and quantitative forage availability (Leaver, 1985). Differences in naturally occurring shelter may also account for discrepancies between studies. The variation accounted for by the acclimation lags demonstrating significance for MDT and STTS was similar and very small (Adj R-sq = .08). Therefore, as with Beverlin et al. (1989), the biological importance of a singular acclimation lag representing the time course of thermal acclimation (Senft and Rittenhouse, 1985) during the winter was discounted.

The presence of fecal bags (Chapter 2) caused a mean reduction in DGT of 54 min ($P < .001$) over all acclimated temperatures for 1-20 days. Thus, fecal bags used for total fecal collections had a substantial effect on the amount of time cows spent grazing.

Trial 2

Mean DGT during Trial 2 (482 ± 3.7 min/day) was less than grazing times observed during the winter season in the present and previous studies at the same study site (Dunn et al., 1988; Beverlin et al., 1989).

Stepwise regression analysis indicated that the final model should include linear, quadratic and cubic terms for MDT, linear and quadratic terms for STTS, and fecal bag and

the MDT X STTS interaction as independent variables. Effects of MDT and STTS on DGT for acclimated temperatures of 1 to 20 days are given in Table 4. Mean daily temperature had a cubic influence on DGT ($P < .001$) for acclimated temperatures of 1 to 20 days. The positive nonlinear response of DGT to MDT indicates that cows generally graze less at colder temperatures. This finding is in agreement with the positive linear response of grazing times to minimum daily temperature reported by others (Malechek and Smith, 1976; Adams et al., 1986) during late fall and early winter. Short-term thermal stress using acclimated temperatures calculated for lags of 1 to 7 and 15 to 19 days had a significant nonlinear effect on DGT ($P < .05$). There was a linear decrease in DGT due to STTS calculated for acclimated temperatures of 8 to 14 and 20 day lags ($P < .001$).

Senft and Rittenhouse (1985) hypothesized that under free ranging conditions, cattle exhibit foraging behaviors independent of temperatures falling within the thermoneutral zone. A subjective review of these data suggests that during the fall season there may be a very narrow range of temperatures (2 to 8 C) within which free-ranging cattle graze independently of ambient temperature and respond only to STTS. At intermediate temperatures which occurred during Trial 2 (2 to 8 C), cows appeared to be insensitive to changes in ambient temperature and maximized grazing when there was little or no

Table 4. Responses of daily grazing time (DGT) to mean daily temperature (MDT) and short-term thermal stress (STTS) for acclimation lengths (LAG) of 1 to 20 days (Trial 2).^{ab}

LAG	Parameter					
	MDT	MDT ²	MDT ³	STTS	STTS ²	MDT*STTS
1	3.97 ^e	-1.54 ^e	.09 ^e	-3.66 ^d	-.51 ^d	.39 ^d
2	6.47 ^e	-1.83 ^e	.09 ^e	-7.81 ^e	-.68 ^e	.93 ^e
3	7.35 ^e	-1.90 ^e	.10 ^e	-8.92 ^e	-.69 ^e	.99 ^e
4	6.58 ^e	-2.05 ^e	.12 ^e	-9.26 ^e	-.67 ^e	.93 ^e
5	6.63 ^e	-2.07 ^e	.12 ^e	-10.09 ^e	-.74 ^e	.93 ^e
6	5.73 ^e	-1.94 ^e	.12 ^e	-9.71 ^e	-.62 ^e	.71 ^d
7	5.31 ^e	-1.76 ^e	.11 ^e	-8.21 ^e	-.43 ^d	
8	3.12 ^c	-1.58 ^e	.12 ^e	-7.20 ^e		
9	3.51 ^c	-1.56 ^e	.12 ^e	-6.99 ^e		
10	3.27 ^c	-1.57 ^e	.12 ^e	-7.49 ^e		
11	3.82 ^c	-1.64 ^e	.12 ^e	-8.35 ^e		
12	4.33 ^d	-1.75 ^e	.12 ^e	-9.43 ^e		
13	3.05 ^c	-1.75 ^e	.14 ^e	-9.21 ^e		
14	3.87 ^c	-1.83 ^e	.14 ^e	-9.74 ^e		
15	6.55 ^d	-2.03 ^e	.13 ^e	-11.24 ^e	-.53 ^d	.94 ^d
16	8.34 ^e	-2.30 ^e	.13 ^e	-12.39 ^e	-.68 ^d	1.43 ^d
17	9.41 ^e	-2.35 ^e	.12 ^e	-12.76 ^e	-.70 ^d	1.57 ^d
18	12.71 ^e	-2.78 ^e	.12 ^e	-14.64 ^e	-.95 ^e	2.44 ^e
19	13.12 ^e	-2.77 ^e	.12 ^e	-14.19 ^e	-.73 ^d	2.38 ^e
20	14.54 ^e	-2.84 ^e	.12 ^e	-15.82 ^e	-1.03 ^c	2.63 ^d

^aModel for each lag (1-20) significant (P<.001).

^bMagnitude of response is min per degree C and degree STTS.

^cP<.1, (linear term must remain in the model if upper order variables are significant).

^dP<.05, ^eP<.001.

STTS. Outside of this narrow range, alterations in DGT occurred as a result of increased or decreased MDT and does not support the hypothesis of Senft and Rittenhouse (1985).

The positive STTS value of greatest magnitude was 12.13 C. The largest negative STTS observed was -15.97 C. There

were more positive than negative STTS values observed at higher temperatures and a greater number of negative values at lower temperatures. This may explain the significant ($P < .05$) interaction between MDT and STTS for lags of 1 to 6 and 15 to 20 days.

Thus, DGT of free-ranging beef cows appeared to be responsive to both MDT and STTS during the fall. The response to STTS was not entirely independent of MDT. The model constructed for a 5d acclimation lag provided the best fit (Adj R-sq = .30) to the data and may therefore best describe the response of DGT to MDT and STTS during the fall season. Daily grazing time predicted by the model at MDT (16.33, -9.27) and STTS (12.13, -15.97) of largest observed positive and negative magnitudes were 544 and 288 min, respectively. The result is a substantial increase (62 min) or decrease (194 min) from mean DGT. Figure 6 illustrates the greater sensitivity of free-ranging beef cows to the thermal conditions observed during the fall (Trial 2) than grazing times recorded during the winter (Trial 1) at the same study site.

Due to a malfunction in the electronic meteorograph ambient temperatures were not recorded prior to October 11. Therefore, acclimation lengths of 1 to 20 days could not be calculated over the same number of days and range of mean daily temperatures, and no conclusions could be made concerning the time course of thermal acclimation.

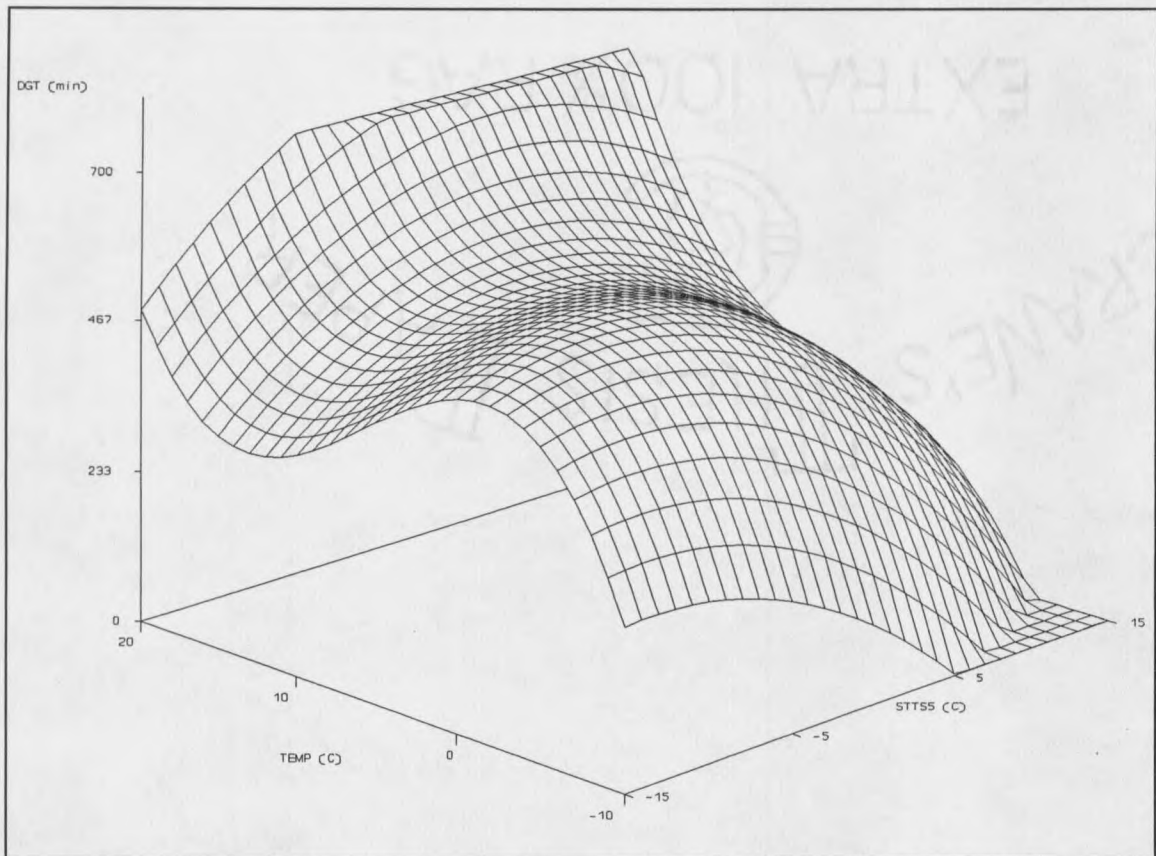


Figure 6. Effect of mean daily temperature (MDT) and short-term thermal stress (STTS) on daily grazing time (DGT) during Trial 2. $DGT = 512.21 + 6.63(MDT) - 2.07(MDT^2) + .12(MDT^3) - 10.09(STTS) - .74(STTS^2) + .93(MDT*STTS)$.

The differences in the response of DGT to the thermal conditions observed between Trial 1 and Trial 2 may best be explained by thermal acclimation. When an environment presents novel or unfamiliar characteristics, stressor effects are more pronounced (Levine, 1985). Exposure to declining and fluctuating temperatures during the fall (Trial 2) may have been novel in comparison to the variable but consistently cold temperatures observed during the winter (Trial 1) and may account for the substantial behavioral response observed. As

an animal is repeatedly exposed to a stressor, subsequent reactions diminish (Levine, 1985). The mid-winter insensitivity to the thermal environment experienced during Trial 1 may have been the result of physiological adaptation to low and unstable ambient temperatures. This adaptation would be a function of both duration of exposure during the previous fall season and previous grazing experiences within the thermal environment. It is unknown if the behavioral adjustments observed during this study represented any physiological changes. Thus, free-ranging beef cows appear to be more responsive to thermal conditions during the fall season than during the winter. It is possible that other foraging behaviors such as rates of forage intake and choice of grazing locations may alter in response to MDT and STTS.

Total fecal collections (Chapter 2) reduced DGT ($P < .001$) by an average of 49 min over all acclimated temperatures for 1 to 20 days. It appears that total fecal collections have a substantial negative effect on the amount of time cows spend grazing.

CHAPTER 4

CONCLUSIONS

The fall season was characterized by a thermal environment with widely fluctuating and declining ambient temperatures. Under these conditions, free-ranging beef cows altered daily grazing time in response to mean daily temperature and short-term thermal stress. The animals grazed less at colder temperatures and when environmental conditions deviated from acclimated temperatures calculated for lags of 1 to 20 days. Organic matter intake was reduced only slightly at colder temperatures and demonstrated a negative response to short-term thermal stress with increased forage intake at negative stress values. It was concluded that these small adjustments in forage intake were of little biological importance. Thus, during the fall transitional period, prepartum beef cows alter duration of forage harvest but maintain consistent levels of intake. It appears that alterations in rates of harvest may also occur in response to thermal stressors. This may depress the animals' ability to graze selectively and result in diets of lower nutritive value.

Winter thermal regimes were characterized by fluctuating

but consistently cold temperatures. Free-ranging cows exposed to these conditions decreased daily grazing time and organic matter intake slightly in response to declines in mean daily temperature. Short-term thermal stress generally resulted in a small reduction in time spent grazing and forage intake at positive deviations but increased when negative stress values occurred. The minimal behavioral responses indicated that prepartum cows grazing familiar winter ranges are relatively unaffected by changes in mean daily temperature and short-term thermal stress. The mid-winter insensitivity to the winter thermal environment is attributed to physiological acclimation to low and unstable ambient temperatures. In summary, daily grazing time of free-ranging beef cows appears to be more responsive to thermal conditions during the fall season than during the winter; however, consistent forage intake is maintained during both initial and prolonged exposure to fluctuating and cold temperatures.

Biological ramifications for the animals as a result of alterations in foraging behavior may be classified as physiological stress (harmless), overstress (some damage) or distress (pathological) (Ewbank, 1985). The relatively constant daily grazing times and forage intake observed during the winter season is an indication that the animals were acclimated to cold exposure. The winter thermal conditions encountered would then be considered as physiological stress. The alterations in foraging patterns created by the fall

thermal environment were not considered severe. For mid-gestational conditions, impacts upon cows at maintenance requirements would be minimal, categorizing these fall thermal conditions also as a physiological stress. Ingram and Dauncey (1985) indicated that the behavioral response to thermal conditions is dependent on the magnitude of the stressor and the time for which the conditions persist. It is possible that if conditions are severe and persist over an extended period of time, the impact on the nutritional status of free-ranging cows could be substantial.

The presence of fecal bags reduced daily grazing time substantially during both the fall and winter seasons. However, there was little effect on organic matter intake of animals used for total fecal collections. It was concluded that animals compensate for decreased time spent grazing by increasing rates of harvest when subjected to wearing fecal bags.

REFERENCES CITED

- Adams, D.C., T.C. Nelsen, W.L. Reynolds and B.W. Knapp. 1986. Winter grazing activity and forage intake of range cows in the Northern Great Plains. *J. Anim. Sci.* 62:1240-1246.
- Allison, C.D. 1985. Factors affecting forage intake by ruminants: a review. *J. Range Manage.* 38:305-311.
- Arnold, G.W. and M.L. Dudzinski. 1978. *Ethology of the Free-Ranging Domestic Animal*. Elsevier Scientific Publishing Amsterdam. 198 pp.
- Association of Official Agriculture Chemists (AOAC). 1980. *Official Methods of Analysis* (13th ed.) Assoc. Official. Agric. Chem. Washington, D.C. 970 pp.
- Beverlin, S.K. 1988. Winter foraging behaviors in relation to acute thermal stresses and supplementation. M.S. Thesis. Montana State University, Bozeman, MT. 81 pp.
- Beverlin, S.K., K.M. Havstad, E.L. Ayers and M.K. Petersen. 1989. Forage intake responses to winter cold exposure of free-ranging beef cows. *Appl. Anim. Behav. Sci.* 23:75-85.
- Cook, C.W. and L.E. Harris. 1968. The nutritive value of seasonal ranges. *Utah Ag. Exp. Sta. Bull.* 472. Utah State University, Logan, UT. 55 pp.
- Costigan, P. and K.J. Ellis. 1986. Analysis of faecal chromium derived from controlled marker devices. *New Zealand J. Technol. Res.* 3:89-92.
- Dunn, R.W. 1986. Physiological and behavioral responses of cows on Montana foothill range to winter and supplement. M.S. Thesis. Montana State University, Bozeman, MT. 83 pp.
- Dunn, R.W., K.M. Havstad and E.L. Ayers. 1988. Grazing behavior responses of rangeland beef cows to winter ambient temperatures and age. *Appl. Anim. Behav. Sci.* 21:201-207.

- Ewbank, R., 1985. Behavioral responses to stress in farm animals. In: G.P. Moberg (Editor). Animal Stress. Amer. Physiol. Soc., Bethesda, Maryland. pp 71-80.
- Fenton, T.W. and M. Fenton. 1979. An improved procedure for the determination of chromic oxide in feed and feces. Can. J. Anim. Sci. 59:631-634.
- Harris, L.E. 1970. Nutritional Research Techniques for Domestic and Wild Ruminants. Vol. 1. L.E. Harris Pub., Logan, Ut. 187 pp.
- Ingram, D.L. and M.J. Dauncey. 1985. Thermoregulatory behavior. In: M.K. Yousef (Editor). Stress Physiology in livestock: volume I. CRC Press., Boca Raton, FL. pp 97-108.
- LaMontagne, F.A.D. 1981. Response of cull cows to different ration concentrate levels. M.S. Thesis, Montana State University, Bozeman, MT. 77 pp.
- Leaver, J.D. 1985. Milk production from grazed temperate grassland. J. Dairy Res. 52:313-344.
- Lesperance, A.L., V.R. Bohman and D.W. Marble. 1960a. Development of techniques for evaluating grazed forage. J. Dairy Sci. 43:682-689.
- Levine, S. 1985. A definition of stress? In: G.P. Moberg (Editor) Animal Stress. Amer. Physiol. Soc., Bethesda, Maryland. pp 51-70.
- Malecheck, J.C. and B.M. Smith. 1976. Behavior of range cows in response to winter weather. J. Range Manage. 29:9-12.
- Osuji, P.O. 1974. The physiology of eating and the energy expenditure of the ruminant at pasture. J. Range Manage. 27:437-443.
- Raleigh, R.J., R.J. Kartchner and L.R. Rittenhouse. 1980. Chromic oxide in range nutrition studies. Oregon State University. Ag. Exp. Sta. Bull. 641. 41 pp.
- SAS, 1988. SAS User's Guide: Statistics. Statistical Analysis Systems Institute Inc., Cary, NC. 956 pp.
- Senft, R.L. and L.R. Rittenhouse. 1985. A model of thermal acclimation in cattle. J. Anim. Sci. 61:297-306.
- Stobbs, T.H. 1970. Automatic measurement of grazing time by dairy cows on tropical grass and legume pastures. Trop. Grassl. 4:237-244.

Turner, M.E. 1985. The forage intake of supplemented cows grazing winter foothill rangelands of Montana. M.S. Thesis, Montana State University, Bozeman, MT. 68 pp.

Young, B.A. 1975. Effects of winter acclimatization on resting metabolism of beef cows. Can. J. Anim. Sci. 55:619-625.

APPENDIX

Table 5. Weekly means of dietary in vitro organic matter digestibility (IVOMD) from rumen extrusa (Trial 1).^a

Week	IVOMD(%)
1/03-1/09	24.60±0.70
1/10-1/16	30.96±0.87
1/17-1/23	27.67±1.02
1/24-1/30	26.70±0.51
1/31-2/06	28.35±0.70
2/07-2/13	28.56±1.46
2/14-2/20	29.06±1.27
2/21-2/27	26.99±0.52
Overall	27.86±0.42

^aMean±SE

Table 6. Weekly means of dietary in vitro organic matter digestibility (IVOMD) from rumen extrusa (Trial 2).^a

WEEK	IVOMD(%)
10/08-10/14	35.84±1.51
10/15-10/21	36.36±1.02
10/22-10/28	35.35±1.86
10/29-11/04	32.92±2.65
11/05-11/11	36.54±0.96
11/12-11/20	32.74±2.09
11/19-11/25	30.97±1.91
11/26-12/02	29.53±0.78
Overall	33.78±0.68

^aMean±SE

Table 7. Fecal organic matter output (FO) and organic matter intake (OMI) as a percentage of body weight (%BW) estimated from rectal grab samples for each cow (Trial 1).^a

Cow	FO (%BW)	OMI (%BW)
1	.72±.01	1.00±.02
2	.75±.02	1.04±.03
3	.71±.01	0.99±.02
4	.75±.01	1.05±.01
5	.80±.01	1.11±.02
6 ^b		
7	.85±.01	1.18±.02
8	.76±.01	1.08±.02
9	.85±.01	1.18±.02
10	.81±.01	1.13±.02
11	.76±.01	1.07±.02
12	.82±.01	1.14±.02
13	.72±.01	1.00±.01
14	.83±.01	1.15±.02
15	.80±.01	1.11±.02
16	.81±.01	1.12±.02
Overall	.79±.004	1.09±.005

^aMean±SE

^bCow 6 was not pregnant and was not included in the analysis.

Table 8. Fecal organic matter output (FO) and organic matter intake (OMI) as a percentage of body weight (%BW) estimated from rectal grab samples for each cow (Trial 2).^a

Cow	FO (%BW)	OMI (%BW)
1	.65±.01	0.96±.02
2	.76±.01	1.15±.02
3	.73±.01	1.10±.02
4	.65±.01	0.98±.02
5	.70±.01	1.06±.02
6	.81±.01	1.22±.02
7	.70±.01	1.06±.02
8	.69±.01	1.05±.02
9	.74±.01	1.12±.02
10	.74±.01	1.12±.02
11	.80±.01	1.21±.02
12	.67±.01	1.01±.02
Overall	.72±.004	1.09±.006

^aMean±SE

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