



Grazing behavior of rangeland beef cows differing in milk production
by William James Lathrop

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

Montana State University

© Copyright by William James Lathrop (1985)

Abstract:

It was the purpose of this study to evaluate the differences in grazing behavior among straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1SIH) and 75% Simmental-25% Hereford (3S1H) lactating cows. A total of 48 cows were divided into two groups, each group containing six cows from each of the four breed types. The study consisted of four 10-d grazing periods starting on July 22 and ending on August 30. Cow weight (BW), calf weight (CW) and milk production (MP) estimates were taken prior to periods 1 and 4. Cow condition was estimated using the weight/height ratio and the average calf age was 105 days (range, 85 to 124 days). Cows roamed freely in a 320 ha pasture with slopes ranging from 5 to 40%. Vibracorders and pedometers were used to estimate time spent grazing and distance traveled, respectively. During periods 1, 2 and 4, the 48 study cows were located on a daily basis between 600-900 hr by the use of an aerial photo map. From the recorded locations, distribution of grazing was calculated for each cow. The overall daily grazing mean was 9.4 hr/d (633 observations). No significant breed type differences were found in daily grazing hours. Breed type means were 9.2, 9.6, 9.2 and 9.3 hr/d for HH, AH, 1SIH and 3S1H cows, respectively. Daily grazing hours increased from 8.0 hr/d in period 1 to 10.0 hr/d in period 4. Of the cow and calf traits used as covariates, only MP and calf age had any significant effects on time spent grazing. The partial regression coefficients for MP and calf age were .05 hr/d/kg/d and -.02 hr/d/d, respectively (adjusted for BW). The increase in grazing time due to increased MP was mainly between 2400-300 hr. The overall distance traveled mean was 4.7 km/d (82 observations) and followed the same trend as time spent grazing. Two hr/d were spent grazing for every km of travel during the four grazing periods. 1SIH cows traveled less ($P < .05$) than HH, AH and 3S1H cows. Breed type means were 5.0, 4.8, 4.1 and 4.8 km/d for HH, AH, 1SIH and 3S1H cows, respectively. The overall distribution mean was 103 ha/cow (47 observations). Breed type was not significant in explaining the variation in distribution of grazing. Breed type means were 105, 115, 93 and 99 ha/cow for HH, AH, 1SIH and 3S1H cows, respectively. For every kg increase in CW (adjusted for cow condition), distribution of grazing increased by .5 ha ($P < .05$). Also, for every ha increase in distribution of grazing, cows gained .3 kg in body weight ($P < .01$).

GRAZING BEHAVIOR OF RANGELAND BEEF COWS
DIFFERING IN MILK PRODUCTION

by

William James Lathrop

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Animal Science

MONTANA STATE UNIVERSITY
Bozeman, Montana

December 1985

MAIN LIB.
N378
L348
Cop. 2

ii

APPROVAL

of a thesis submitted by

William James Lathrop

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.

12/3/85
Date

D D Kress
Chairperson, Graduate Committee

Approved for the Major Department

Dec 3, 1985
Date

Arthur C. Linton
Head, Major Department

Approved for the College of Graduate Studies

12-5-85
Date

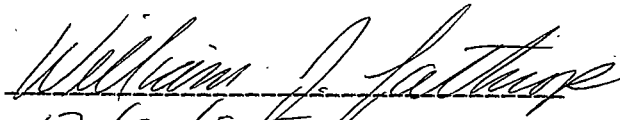
W B Malow
Graduate Dean

STATEMENT OF PERMISSION TO USE

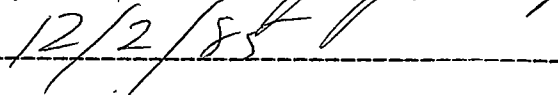
In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the library shall make it available to borrowers under rules of the library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgement of source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Director of Libraries when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature



Date



ACKNOWLEDGEMENTS

During the past few years, I have attempted to accomplish what, at times, seemed to be an impossible task. From the start to the finish, each day has brought a new meaning to the word frustration. Thanks to several people, I can now look back at the experience and feel a sense of accomplishment.

To Don Kress, Kris Havstad, Pete Burfening and Dan Doornbos, thanks for providing the moral support and guidance I needed to achieve my goal. I hope you are pleased with my performance as a graduate student.

To Steve Kachman and Kathy Hanford, thanks for leading me through the maize of confusion associated with statistics. I never would have made it without your help.

To my fellow graduate students, thank you for the good times we shared. These memories will never be forgotten.

To Matt Wagner, my research partner and personal friend, I would have never made it without your help. I thank you for the countless hours you spent on this project and your uplifting sense of humor helped me through two summers in Havre.

Most important, to my wife Kathy, thank you for being there when I needed you. They say that behind every successful man is a good woman. I should go far because I have the best.

TABLE OF CONTENTS

	Page
LIST OF TABLES	vi
LIST OF FIGURES	vii
ABSTRACT	viii
INTRODUCTION	1
LITERATURE REVIEW	4
Energy Required For Maintenance	4
Forage Quantity and Quality	6
Climate Influences	10
Animal Features	11
Physical Environment	13
MATERIALS AND METHODS	17
Statistical Analysis	21
RESULTS AND DISCUSSION	24
Daily Grazing Hours	27
Time of Day Grazing	33
Distance Traveled	41
Distribution of Grazing	43
Speculation and Future Direction	46
SUMMARY	50
LITERATURE CITED	53
APPENDIX	60

LIST OF TABLES

Table	Page
1. Observation periods and dates	20
2. Least-squares analyses of variance for cow body weight, milk production and calf weight	25
3. Least-squares means and standard errors for cow body weight, milk production and calf weight	26
4. Least-squares analysis of variance for daily grazing hours	28
5. Least-square means and standard errors for daily grazing hours of the interaction between breed and period(group)	31
6. Effects of covariates on daily grazing hours	32
7. Least-squares analyses of variance for time of day grazing (2400-1200 hr)	34
8. Least-squares analyses of variance for time of day grazing (1200-2400 hr)	35
9. Least-squares means for time of day grazing	37
10. Least-squares means for time of day grazing (0300-0600 and 1800-2100 hr) for the interaction between breed type and period(group)	39
11. Least-squares analysis of variance for distance traveled	42
12. Least-squares analysis of variance for distribution of grazing	44
13. Residual correlations between grazing behavior variables and cow and calf traits	61
14. Residual correlations between daily grazing hours and time of day grazing	62

LIST OF FIGURES

Figure	Page
1. Map of pasture	18
2. Overall time of day grazing means	36

ABSTRACT

It was the purpose of this study to evaluate the differences in grazing behavior among straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1S1H) and 75% Simmental-25% Hereford (3S1H) lactating cows. A total of 48 cows were divided into two groups, each group containing six cows from each of the four breed types. The study consisted of four 10-d grazing periods starting on July 22 and ending on August 30. Cow weight (BW), calf weight (CW) and milk production (MP) estimates were taken prior to periods 1 and 4. Cow condition was estimated using the weight/height ratio and the average calf age was 105 days (range, 85 to 124 days). Cows roamed freely in a 320 ha pasture with slopes ranging from 5 to 40%. Vibracorders and pedometers were used to estimate time spent grazing and distance traveled, respectively. During periods 1, 2 and 4, the 48 study cows were located on a daily basis between 600-900 hr by the use of an aerial photo map. From the recorded locations, distribution of grazing was calculated for each cow. The overall daily grazing mean was 9.4 hr/d (633 observations). No significant breed type differences were found in daily grazing hours. Breed type means were 9.2, 9.6, 9.2 and 9.3 hr/d for HH, AH, 1S1H and 3S1H cows, respectively. Daily grazing hours increased from 8.0 hr/d in period 1 to 10.0 hr/d in period 4. Of the cow and calf traits used as covariates, only MP and calf age had any significant effects on time spent grazing. The partial regression coefficients for MP and calf age were .05 hr/d/kg/d and -.02 hr/d/d, respectively (adjusted for BW). The increase in grazing time due to increased MP was mainly between 2400-300 hr. The overall distance traveled mean was 4.7 km/d (82 observations) and followed the same trend as time spent grazing. Two hr/d were spent grazing for every km of travel during the four grazing periods. 1S1H cows traveled less ($P < .05$) than HH, AH and 3S1H cows. Breed type means were 5.0, 4.8, 4.1 and 4.8 km/d for HH, AH, 1S1H and 3S1H cows, respectively. The overall distribution mean was 103 ha/cow (47 observations). Breed type was not significant in explaining the variation in distribution of grazing. Breed type means were 105, 115, 93 and 99 ha/cow for HH, AH, 1S1H and 3S1H cows, respectively. For every kg increase in CW (adjusted for cow condition), distribution of grazing increased by .5 ha ($P < .05$). Also, for every ha increase in distribution of grazing, cows gained .3 kg in body weight ($P < .01$).

INTRODUCTION

The range animal grazes over a variety of plant communities. Grazing on any plant community will often result in the selection of certain preferred plant species and plant parts (Arnold and Dudzinski, 1978). This selective process not only affects the composition of forage consumed but also the quantity and quality of the forage available to the animal. As a result of this selective nature, the free-roaming animal spends more time eating and foraging for food than the confined animal. This extra muscular activity can have a considerable impact upon the animal's maintenance energy requirement (Osuji, 1974). It has been estimated that the grazing animal requires 40 to 70% more dietary energy than the confined animal (Graham, 1964; Young and Corbett, 1972; Havstad and Malecheck, 1982). Osuji (1974) suggested that the increase in the animal's maintenance requirement is probably due to the energy costs associated with eating, walking and the work of digestion done by the gut in handling bulky pasture materials. Conventional estimates of the energy required for maintenance have been made with animals housed indoors in respiration chambers. In order to meet the range animal's maintenance requirement, livestock producers need to account for the added costs associated with the animal's activities at pasture.

The energy cost of eating has been estimated to be from 0.26 to 0.83 kcal/kg/hr (Osuji, 1974). Arnold and Dudzinski (1978) reviewed the literature and reported grazing times ranging from 5 to 13 hr/d

with the majority of estimates being between 9 to 10 hr/d. The energetic cost of travel on level terrain has been estimated to be from 0.45 to 0.78 kcal/kg/km (Blaxter, 1962; Graham, 1964; Osuji, 1974) with the cost of ascent being ten times as costly (Clapperton, 1964). Cattle have been estimated to travel distances up to 14 km/d (Herbel and Nelson, 1966).

Under extensive range conditions, the increase in energy expenditure could be even greater. Rangelands often exhibit complex combinations of vegetative communities, topography and water distribution. Uniform distribution of grazing is difficult to achieve and large areas of the range go ungrazed while other areas are severely overgrazed. Animals may be forced to travel long distances, possibly over rough terrain, in search of food and water. Uneven use of rangeland can be detrimental to both forage and animal productivity (Arnold and Dudzinski, 1978).

To more fully exploit animal production on rangelands, a more complete understanding of the animal's feeding activities is essential. The major emphasis of this study was to evaluate the grazing behavior of four genotypically different types of beef cattle (straight Hereford, 50% Angus-50% Hereford, 50% Simmental-50% Hereford, 75% Simmental-25% Hereford) grazing rangeland. Past research has shown these four breed types to be different in forage consumption (Kronberg et al., 1983; Wagner et al., 1985), milk production (Casebolt et al., 1984), dam performance and overall productivity (Kress et al. 1984b) and calf performance (Kress et al., 1984b; Kress et al., 1985). The specific objectives were to quantify the major

free-roaming diurnal activities (distance traveled and time spent grazing), characterize distribution of grazing and estimate the relationship between animal grazing behavior and animal production.

LITERATURE REVIEW

Grazing is the act of foraging for food and the process involves standing, eating and both horizontal and vertical movement. Behavior can be defined as the response of an animal to its environment. Grazing behavior is concerned with how the process of grazing is affected by the environment in which the animal finds itself.

The focus of this literature review is on the energetic cost of the grazing process to the animal and those animal and environmental factors that influence the degree of energy being expended.

Energy Required For Maintenance

The energy required for maintenance (NEm) can be defined as that amount of feed energy that will result in no loss or gain in body energy and is the amount of energy equivalent to the fasting heat production (NRC, 1984). The heat produced under fasting conditions is proportional to the animal's metabolic rate which increases with increasing body size. Kleiber (1965) estimated that body size was most accurately expressed as body weight raised to the .75 power. Blaxter (1962) reviewed the literature on metabolic rate and found that adult cattle have on the average a metabolic rate of 81 kcal/kg BW^{.75}. Currently, the National Research Council (NRC, 1984) is using 77 kcal/kg BW^{.75} as the metabolic rate for cattle as established by Lofgreen and Garrett (1968).

The maintenance requirement is most applicable for animals in

nonstressful environments with minimal activity. For the free-roaming animal, the maintenance requirement includes the added energy costs associated with eating, walking, work of digestion (Osuji, 1974) and thermoregulation. Havstad and Malechek (1982) reported an energy expenditure of 161 kcal/kg BW^{.75}/day for free-ranging heifers. This was 46% greater than the 110 kcal/kg BW^{.75}/day estimated for stall-fed heifers. For grazing sheep, increases in energy expenditure of 30% to 70% have been reported (Young and Corbett, 1972; Osuji, 1974).

The energy cost of merely standing has been estimated to be from 0.06 to 0.38 kcal/kg/hr (Osuji, 1974). Webster and Valks (1966) estimated a 12% increase in energy expenditure of standing over lying. Depending on the type of diet and the measuring techniques used, the energetic cost of eating has been estimated to be from 0.26 to 0.83 kcal/kg/hr (Osuji, 1974). Graham (1964) reported a value of 0.54 kcal/kg/hr for sheep consuming a roughage diet and the cost was the same whether the meal was cut or uncut. This assumes that there is no energetic cost to harvesting the forage, however Young (1966) concluded that the changes in energy expenditure during eating were due to prehension and mastication. Holmes (1978) observed similar values with cattle consuming cut pasture but observed a mean value of 0.67 kcal/kg/hr for cattle grazing on standing crop. The latter value includes horizontal movement and probably is a more accurate measurement of the energy cost of grazing. The energetic cost of travel on level terrain has been estimated to be between 0.45 and 0.78 kcal/kg/km (Blaxter, 1962; Graham, 1964; Osuji, 1974; Ribeiro, 1977). Clapperton (1964) found the energy cost of horizontal movement

increased with speed and the cost of ascent was ten times as costly as that on level terrain.

The process of grazing can be extremely costly if the animal spends an appreciable amount of time on the activity, especially if the animal travels large distances in the process. The situation becomes even worse when animals graze on steep slopes and travel long distances when not grazing. Such conditions are typically found on many mountain rangelands and, as a result, the maintenance requirement of the animal grazing rangeland could be extremely high.

Forage Quantity and Quality

Two of the most important environmental factors influencing animal grazing behavior are forage quantity and quality. There has been general agreement that cattle prefer some plant species over others and select leaf in preference to stem and green material in preference to dry material. The material selected, compared with the material from which it was selected, is usually higher in nitrogen, phosphate and gross energy (Arnold, 1964). This selective nature not only affects the composition of the forage consumed but also has a direct influence upon the quantity and quality of the forage available to the animal.

The quantity of forage consumed (intake) is proportional to the amount of time spent grazing, the biting rate and the bite size. The interrelationships between these variables will vary with the physical structure of the forage (bulk, density, height) (Arnold and Dudzinski, 1978) and with the quality of the forage (green vs. dry, leaf vs. stem). There is no set pattern of adjustment to meet a particular

intake level under different forage conditions. In general, as the forage quantity and quality decreases, the animal decreases the size of bite and increases the biting rate (Chacon and Stobbs, 1976; Hendricksen and Minson, 1980). The size of bite taken decreases as quantity of leaf (Chacon and Stobbs, 1976), forage height (Allden and Whittaker, 1970) and forage density (Arnold and Dudzinski, 1978) decreases. Stobbs (1973) stated that a high forage density, a low stem content and a high leaf/height ratio were the major factors influencing bite size of cattle on tropical pastures. The biting rate increases as forage height and availability (Allden and Whittaker, 1970; Scarnecchia et al. 1985) and quantity of leaf (Chacon and Stobbs, 1976) decreases. Uniformity of vegetation could also have a influence on biting rate. Scarnecchia et al. (1985) observed higher biting rates on pastures with uniform forage distribution than on pastures with patchy forage distribution. They concluded that low biting rates were associated with an increase in time spent searching between bites.

The product of bite size and biting rate is intake rate (g/min). As the amount of forage present begins to decline the animals intake rate is at first unaffected; then a stage is reached when forage availability apparently imposes limitations on the rate at which the animal can ingest its feed and intake rate declines (Arnold and Dudzinski, 1978). Allden and Whittaker (1970) found that sheep on pastures containing a mixture of ryegrass, bromegrass and subterranean clover were able to maintain a constant rate of intake when the forage height was between 36.7 and 7.7 cm, but when forage height fell below

7.7 cm the animals were unable to compensate for reduced size of bite by increasing biting rate.

If intake levels are to be maintained, the animal has to increase the amount of time spent grazing to compensate for the decrease in intake rate. Havstad et al. (1983) found that on crested wheatgrass pastures, Angus heifers were able to maintain intake levels when the amount of available forage decreased from 920 to 140 kg DM/ha. On the same type of pasture, Scarnecchia et al. (1985) found that as forage availability decreased from 919 to 144 kg DM/ha, grazing time increased from 6.3 to 10.9 hr/day and biting rate increased from 37 to 50 bites/min. During this same study, Nastis (1979) observed no difference in intake as forage availability decreased. On higher yielding pastures, Allden and Whittaker (1970) found that at forage availabilities greater than 3000 kg DM/ha, both grazing time and rate of intake of green material were relatively constant. As the amount of dry matter fell from 3000 to 500 kg DM/ha, there was a reduction in the rate of consumption from 30 to 5 g/min and an increase in time spent grazing from 6.7 to 11.7 hr/day.

The limit to which the animal can compensate for decreasing forage availability can depend upon the condition of the animal. Arnold and Dudzinski (1978) reviewed the literature and reported grazing times for cattle ranging from 5 to 13 hr/d with the majority falling between 9 to 10 hr/d. Stobbs (1975) reported that fatigue limits the amount of time that can be spent grazing to about 12 hr/day and the number of bites rarely exceeds 36,000/day. Animals in poor condition may not be able to graze as long as those in better shape

and as a result be forced to increase their intake rate. Arnold and Birrell (1977) found when forage availability was low, thin sheep consumed a greater amount of forage in the same amount of time as fat sheep by eating 25% faster.

Since intake is limited by both forage digestibility and availability (Arnold, 1964), the maximum level of compensation can be limited by gut fill. Scarnecchia et al. (1985) noted that when forage availability was at its lowest, grazing time was only 9.4% less than the proposed maximum indicated by Stobbs and forage digestibility (35.3% IVOMD) was probably limiting intake and thus grazing time.

The time of day grazing takes place is also influenced by forage resource. Arnold (1962) found as forage availability decreased, the number of grazing periods decreased from seven to four per day and the average length of a grazing period increased from 1 to 2.5 hr.

Forage quantity and quality also has a major affect on distance traveled. The importance of forage quality and pasture size on distance traveled was illustrated by Anderson and Kothmann (1980) who found that cattle will travel greater distances under a continuous grazing system than under a high-intensity-low-frequency (HILF) grazing system. Heifers under the HILF system traveled 1.5 km/d less than heifers under the continuous system. Crude protein and digestible energy were common independent variables that were significant in explaining the variation in animal travel under both grazing systems. Walker et al. (1985) found different results with mature cows under a short duration grazing system verses a continuous grazing system. Cows on the short duration grazing system tended to walk further than

cows on a continuous grazing system. Quinn and Hervey (1970) controlled forage quantity by using different stocking rates and found that yearling steers traveled significantly less on lightly stocked pastures than steers on moderate and heavy stocked pastures. Over a 15 hr observation period, steers averaged 2.4 km in pastures grazed lightly and 3.2 km in pastures grazed moderate and heavy. They noted that although the distance traveled between moderate and heavy stocked pastures was not different, an entirely different manner of travel was observed between the two intensities. The high amount of travel on the moderately stocked pasture was due to a failure to graze while moving to water or from one area to another, whereas movement on the heavy stocked pasture was mostly while grazing. Thus, the distance an animal travels can be a combination of movement while grazing, movement between grazing areas or movement between water and grazing areas. When water is not readily available, travel to and from water can account for most of the distance traveled (Arnold and Dudzinski, 1978).

Climate Influences

Another important environmental factor influencing grazing behavior is the weather. The time of day that grazing takes place and the total daily grazing time is affected mostly by very cold and very hot and humid conditions. Hancock (1954) observed no correlation between temperature and grazing time when temperatures ranged from 10 to 27 C. Dwyer (1961) found that when the average daily temperature exceeded 30 C. for the day, cows did not spend as much time grazing as when the average temperature was lower than 30 C. Malechek and Smith

(1976) noted that during the winter months cows altered their daily behavioral routines in response to changes in the weather. Time spent grazing was positively correlated (0.65) with air temperature (temperature range, -24 to 5 C) and barometric pressure (0.56). Distance traveled was negatively correlated (-0.90) with wind velocity (velocity range, .4 to 15.5 km/hr). Anderson and Kothmann (1980) reported that precipitation, maximum diurnal temperature and vapor pressure were important in explaining the variation in distance traveled under a high-intensity-low-frequency (HILF) grazing system. From July to December, as the temperature decreased from 35 to -3 C., distance traveled decreased from 5.5 to 2.6 km/d. In Great Britain, Rutter (1968) observed that cattle are more restless, graze less and cover more ground while grazing in cold, stormy or windy weather.

Animal Features

Measurable changes in grazing behavior have been attributed to genotype and physiological state of the animal. Animals with higher intake levels, as determined by energy demand, should express a difference in grazing behavior when compared to animals with lower intake levels (Arnold, 1975). Stricklin et al. (1976), using Angus and Charolais x Angus lactating cows, found that the larger Charolais x Angus cows spent more time grazing in both winter and summer than the smaller Angus cows. During the summer months, Angus cows spent 8.5 hr/d grazing while the Charolais x Angus cows spent 9.0 hr/d grazing. Cow weight was not significant in explaining the variation in daily or daylight grazing hours but was significant in explaining night time grazing hours. The partial correlation coefficient between cow weight

and night grazing was -0.20 , indicating that lighter cows spent more time grazing at night than did heavier cows. Other researchers have also reported a nonsignificant relationship between cow body weight and total daily grazing hours (Brumby, 1959; Stobbs, 1970).

The effect of milk production on grazing time has been documented by several researchers (Hancock, 1954; Arnold and Dudzinski, 1967; Stobbs, 1970). When comparing lactating Jersey and Friesian cows, Brunby (1959) found no differences in grazing time between the two breeds when milk production was held constant. The Friesian cows did have a higher feed intake per kg. of milk produced than the Jersey, but this difference was attributed to a larger maintenance requirement. Stobbs (1970) noted a tendency for high milk producers to have the longest periods of night time grazing. Because of the importance of milk production on grazing time, the differences in grazing time noted by Stricklin et al. (1976) could have been due to the level of milk production.

On a yearlong basis in New Mexico, Herbel and Nelson (1966) found that Hereford cows spent more time grazing, less time walking and traveled less distance than the Santa Gertrudis cows. Breed group means (Hereford, Santa Gertrudis, respectively) were 10.3 and 8.9 hr/d for time spent grazing; 1.6 and 2.9 hr/d for time spent walking; and 7.8 and 12.5 km/d for distance traveled. Hereford cows spent more time grazing at night than Santa Gertrudis cows. Yeates and Murray (1966) have shown that Santa Gertrudis cattle are superior to Herefords in walking ability. Santa Gertrudis heifers had smaller increases in rectal temperature and respiration rate than did Hereford heifers

under conditions of forced exercise. They suggested that the superiority of the Santa Gertrudis may be partly due to higher heat tolerance during exercise.

There seems to be no relationship between intake and grazing time (Stobbs, 1970; Hendricksen and Minson, 1980). Kropp et al. (1973) noted this relationship when investigating the differences in grazing time between Hereford, Holstein and Hereford x Holstein yearling heifers. No differences were found between the three breed groups and the breed group with the highest grazing time gained the least weight. Brumby (1959) showed that grazing time required per unit of intake was greater for Jersey cows than for Friesian cows. Since grazing time and intake rate are both measurements of the effort of grazing, the difference between animals with different intake levels could possibly lie in the area of intake rate. It has been demonstrated that structurally larger animals have a larger rumen volume than smaller animals (Nutt et al., 1980) and sheep with a larger rumen volumes tend to consume food faster than sheep with smaller rumen volumes (Purser and Moir, 1966; Warner and Stacy, 1968). Also, thin sheep have been shown to eat faster than fat sheep (Arnold and Birrell, 1977). Arnold (1975) demonstrated that pregnant and lactating sheep achieve higher intake levels than dry sheep primarily by increasing their intake rate and only on abundant pasture do they graze longer. Whether this relationship holds true for cattle is not known.

Physical Environment

Rangelands often exhibit complex combinations of vegetative

communities, topography and water distribution. Even distribution of grazing is often difficult to achieve and large areas of the range may go ungrazed while other areas are severely overgrazed. As a result, the total available forage and that forage available to the animal may differ. Because of the importance of forage quantity and quality on grazing time and distance traveled, distribution of grazing becomes an important aspect of grazing behavior.

Due to the grazing animal's selective nature, the type of plant communities and plant species present can have a major influence on the degree of use of any given area. Cattle exhibit a marked preference for some plant communities while avoiding others (Roath and Krueger, 1982). Preference is mainly for grasses but as grasses mature they can be replaced by forbes and browse (Cook and Harris, 1968). In general, cattle prefer to graze those areas in which the proportion of palatable and preferred species is greatest (Miller and Krueger, 1976).

The physical structure of the pasture can also have a major impact on the distribution of grazing. Cook (1966) found that percent palatable species had a positive affect on the degree of area utilization, but several other factors appeared to be more important. Six out of the eleven most important variables were concerned with percent slope. Mueggler(1965) found there to be an interaction between distance upslope and slope steepness. On a 10% slope, where access was mainly from the bottom, 75% of cattle use is likely to be within 810 yards of the foot of the slope. On a 60% slope, 75% of use is likely to be within 35 yards of the foot of the slope.

Since water is essential for life, water availability and

distribution is expected to have a major impact on grazing distribution. While there is considerable variation among utilization values for any given distance, there is a consistent trend of decreased utilization as the distance from water increases (Valentine, 1947). Gillen et al. (1984) found that on forested mountain range, cattle preferred areas within 200 m of water and avoided areas greater than 600 m from water. On similar range, Roath and Krueger (1982) reported zero utilization at distances around 1900 m from water.

Other factors that may influence distribution of grazing include aspect of slope (Gonzalez, 1964), surface rock (Gillen, 1983), distance from trails and roads (Roath and Krueger, 1982), salt location and brush thickness (Cook, 1966) and tree cover and down timber (Hedrick et al. 1968).

Because of the complex interactions between the many factors influencing distribution of grazing, no one factor can be used as a reliable indicator in predicting the use of any one area (Gillen, 1983). Using 21 independent variables, Cook (1966) could only account for between 50 to 60% of the variation in the use of mountain slopes. It appears that plant community characteristics, slope gradient and length and water distribution are the major determinants of cattle distribution on mountain ranges (Gillen, 1983). Development of water, fencing and strategic locations for mineral supplements are the primary methods directed towards alleviating these problems (Kothmann, 1980).

The effect of the physical environment on the range animal's grazing behavior has mostly been concerned with distance traveled.

When forage quantity and quality on preferred grazing areas decreases, cattle will travel farther distances, possibly over rough terrain, to less preferred areas. When water is not readily available, travel to and from water can account for most of the distance traveled (Arnold and Dudzinski, 1978). Schmidt (1969), as cited by Arnold and Dudzinski (1978), found that under these conditions cattle may alter their frequency of drinking from one visit to water per day to once every other day. He also observed cattle splitting up into groups, those who forage close to water (nonwalkers) and those who head from water to distant feeding areas (walkers). The only discernible difference between the two groups was the proportion of cows without calves, this being 19% in the nonwalkers and 39% in the walkers. The walkers averaged 16 km/day while the nonwalkers averaged 9.6 km/day.

The importance of the physical environment on time spent grazing is not well documented. Peterson and Woolfolk (1955) observed lower grazing times on a moderately stocked pasture than on a lightly stocked pasture. They concluded that in this case, the shorter grazing time on the moderately stocked pasture resulted from more uniform topography and vegetation subtypes than on the lightly stocked pasture.

MATERIALS AND METHODS

The study was conducted during the summer of 1984 in the Bear Paw Mountains, 32 km southeast of Havre, Montana. The study site had an average elevation of 1300 m with an annual precipitation ranging from 45.7 to 50.8 cm. The pasture used for the study (figure 1) was approximately 320 ha in size and the terrain was rugged with slopes ranging from 5 to 40%. A reservoir and creek were the only sources of available water. A distance of 1.6 km separated the two watering areas. The pasture is traditionally stocked with approximately 250 lactating cows from July 21 to September 1 for a total of 325 AUM's. This can be considered a stocking rate of 1.0 ha/AUM. The pasture is dominated by rough fescue (Festuca scabrella), Idaho fescue (Festuca idahoensis) and bluebunch wheatgrass (Agropyron spicatum) with an open ponderosa pine (Pinus ponderosa) overstory. Kentucky bluegrass (Poa pratensis) dominated the lowland vegetation.

A total of 48 cows were divided into two groups with each group containing six cows from the following four breed types; straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1S1H) and 75% Simmental-25% Hereford (3S1H). The cows used in this study were between 5 and 8 yr of age and selected at random (within breed type) from the cow herd. All cows were lactating and from a common management background. Calves were sired by either Charolais or Tarentaise bulls. Vibracorders, as described by Stobbs (1970), were used to estimate the amount of time spent grazing. Time spent grazing

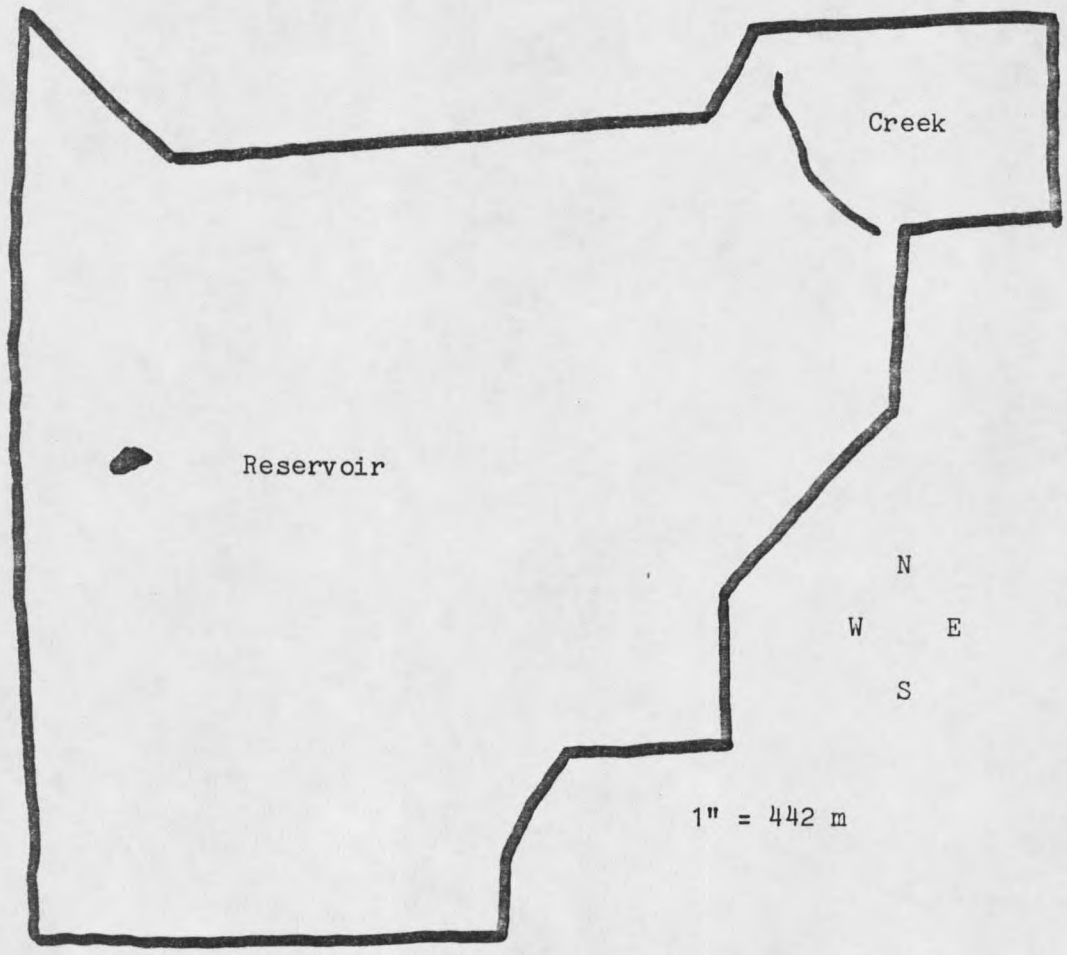


Figure 1. Map of pasture

was determined by estimating grazing activity to the nearest .25 hr. Both daily grazing hours and the time of day grazing took place were analyzed. To estimate the time of day grazing occurred, each day's grazing time was divided into eight 3-hr time periods (2400-0300, 0300-0600, 0600-0900, 0900-1200, 1200-1500, 1500-1800, 1800-2100, 2100-2400).

Pedometers, as described by Anderson and Kothmann (1977), were used to estimate distance traveled. Due to the variation in the length of stride between animals, a calibration factor was calculated by dividing the travel distance measured on the pedometer by the actual distance walked. Five cows (Hereford) were walked a distance of 1.6 km to determine the calibration factor. Daily distance traveled was determined by dividing the pedometer readings by the calibration factor (.8) and then adjusting this distance to a 24-hr basis. Use of the calibration factor adjusted for differences in length of stride within breed type, but did not adjust for differences between breed type. Due to the possible variation in measurements between pedometers, animals were randomly assigned pedometers each time equipment changes were made.

The observation dates are shown in table 1. Equipment was rotated between the two groups of cows every 10-d. The study consisted of four 10-d periods starting on July 22 and ending on August 30. Cow weights, calf weights and milk production estimates were taken prior to periods 1 and 4. After a 7 hr. separation time, cow and calf weights were taken and milk production was estimated using the weigh-suckle-weigh technique (Williams et al., 1979a). Milk production was

Table 1. Observation periods and dates

Group	Period	Dates
2	1	July 22 - July 31*
1	2	Aug. 1 - Aug. 10
2	3	Aug. 11 - Aug. 20
1	4	Aug. 21 - Aug. 30*

* Cow weights, calf weights and milk production estimates were taken prior to these periods.

then converted to a 24-hr basis by multiplying the estimate by 3.4. Cow metabolic body weight (body weight^{.75}) was calculated but was found to be highly correlated with body weight (.99) and not used in any analyses. Cow condition was expressed as the weight to height ratio (Williams et al., 1979b; Dunn et al., 1983) and the average calf age (stage of lactation) was 105 d (range = 85 to 124 d) at the start of the experiment.

Grazing distribution was monitored during grazing periods 1, 2 and 4. The 48 study cows were located on a daily basis between 600 and 900 hr. Preliminary analysis revealed this to be major period of grazing activity. Each animal's location was determined by and recorded on gridded aerial photo maps. A grazing radius was calculated for each cow by finding the geographic center of the grazing locations and then calculating the average distance from the geographic center to each individual observation as outlined by Hayne (1949) and used by Gillen (1983) to estimate the home range size of free-ranging beef cows. The grazing radius was then squared and

multiplied by 3.14 (the area of a circle) to estimate each animal's distribution of grazing.

Using commercially available stock dye, all cows were marked with large numbers to aid in identification. Small portable corrals were placed near water to minimize animal disturbance when equipment changes were made. On days when equipment changes were made, daily grazing and time of day grazing data were not used and animal location was not recorded. The possible number of observations/cow/period for daily grazing hours, time of day grazing hours and distance traveled was eight, eight and one, respectively. For distribution of grazing, only one observation/cow was recorded over the study period.

Statistical Analysis

Data were analyzed by least squares procedures and differences between factor level means were tested using LSD methods (SAS, 1982). All nonsignificant two-way interactions, as revealed by preliminary analyses, were removed to arrive at the final linear models.

A mixed model was employed for analysis of both daily grazing hours and time of day grazing. The linear mathematical model was as follows:

$$Y_{ijklm} = u + B_i + G_j + C_{(k)ij} + P_{(l)j} + D_{(m)lj} + BP_{ilj} + e_{ijklm},$$

where

Y_{ijklm} = an observation

u = the overall mean,

B_i = the fixed effect of the i th breed type,

G_j = the fixed effect of the j th group,

$C_{(k)ij}$ = the random effect of the kth cow within the ith breed within the jth group,

$P_{(l)j}$ = the fixed effect of the lth period within the jth group,

$D_{(m)lj}$ = the fixed effect of the mth day within the lth period within jth group,

BP_{ilj} = the interaction between the ith breed type and the lth period within the jth group,

e_{ijklm} = random error.

Breed type and group were tested using the random effect of cow(breed x group) and all other effects were tested using the residual.

For analysis of distance traveled, a fixed model was employed using breed type, group, period(group), sex of calf and sire breed of calf as fixed main effects. Two-way interactions included breed by period(group) and breed by sire breed of calf.

The model used for distribution of grazing included breed type, sex of calf and sire breed of calf as fixed main effects and no two-way interactions were found to be significant ($P > .10$). Because the number of observations influences the size of the estimated area (Gillen, 1983), the number of observations used to calculate distribution of grazing was included in the model as a continuous independent variable.

Realizing that the mechanisms involved in the control of energy balance are poorly understood (Baile and Forbes, 1974), the point of view taken during this study was that the behavior of the grazing animal is a reflection of its energy requirement. As a result, cow weight, cow milk production and cow condition, along with calf weight

and calf age, were used as covariates whenever possible to determine their effect on daily grazing hours, time of day grazing, distance traveled and distribution of grazing. For daily grazing and time of day grazing, cow(breed x group) was removed from the model and replaced by sex of calf and sire breed of calf. Because the cow and calf measurements were taken prior to periods 1 and 4, the effects of these traits on daily grazing hours, time of day grazing hours and distance traveled are only during these two periods. An average of the measurements recorded in periods 1 and 4 for all the cow and calf traits was used in the distribution model because only one observation/cow for distribution of grazing was measured.

RESULTS AND DISCUSSION

The least-squares analyses of variance for cow body weight, milk production and calf weight for the animals used during the study are presented in table 2. The breed type means and standard errors for these traits (periods 1 and 4) are presented in table 3.

At the beginning of the study (period 1), the Simmental cross cows (1S1H and 3S1H) were heavier ($P < .01$) than the Hereford cows but not heavier than the Angus x Hereford cows. The Angus x Hereford cows were not significantly different from either the Hereford or Simmental cross cows. All breed types maintained their weight for the duration of the trial. Similiar results were observed, at the Northern Agricultural Research Center, by Casebolt (1984). Cow body weight progressively increased during the post peak milk production portion of lactation and no differences were found in the cyclic changes in body weight between these same four breed types.

The Simmental cross cows produced significantly more ($P < .05$) milk than either the HH or AH cows at the start of the study (period 1) (table 3), but by the end of the study (period 4) there was no difference in milk production between the four breed types. The Simmental cross cows significantly decreased in milk production from periods 1 to 4. Casebolt (1984) reported similiar breed type differences with respect to the level of milk production, but found no breed type differences in the shape of the lactation curves. This disagreement, in the shape of the lactation curves, could be

Table 2. Least-squares analyses of variance for cow body weight (BW), milk production (MP) and calf weight (CW)

Source	df	Mean squares		
		BW (kg ²)	MP (kg ² /d ²)	CW (kg ²)
Breed type (B)	3	8068**	59.0**	1535**
Group (G)	1	15475**	21.1	1460**
Period (P)	1	95	57.0*	30856**
Sire breed of calf	1	27045**	20.7	961*
Sex of calf	1	3	1.9	2613**
B x G	3	3760+	17.6	45
B x P	3	336	22.0+	55
Regression				
Age of calf	1	264	7.2	9911**
Residual	79	1471	11.0	199
R ²		0.43	0.32	0.78

+ P<.10

* P<.05

** P<.01

Table 3. Least-squares means and standard errors for cow body weight (BW), milk production (MP) and calf weight (CW)

Period	Breed ^a type	N	Trait ^b		
			BW (kg)	MP (kg/d)	CW (kg)
1	HH	12	552 ± 11 ^c	6.8 ± .9 ^c	155 ± 4.1 ^c
	AH	12	581 ± 11 ^{cd}	7.6 ± 1.0 ^c	151 ± 4.2 ^c
	1S1H	12	599 ± 12 ^d	11.0 ± 1.0 ^d	157 ± 4.4 ^{cd}
	3S1H	12	600 ± 11 ^d	11.7 ± 1.0 ^d	168 ± 4.1 ^d
4	HH	12	565 ± 11 ^c	6.3 ± .9 ^c	188 ± 4.1 ^e
	AH	12	581 ± 11 ^{cd}	8.1 ± 1.0 ^c	185 ± 4.2 ^e
	1S1H	11	594 ± 12 ^d	7.6 ± 1.1 ^c	196 ± 4.4 ^{ef}
	3S1H	12	601 ± 11 ^d	8.8 ± 1.0 ^c	206 ± 4.1 ^f

^a HH = Hereford, AH = 50% Angus-50% Hereford, 1S1H = 50% Simmental-50% Hereford, 3S1H = 75% simmental-25% Hereford.

^b Means in columns with different superscripts are different BW (P<.01), MP and CW (P<.05).

attributed to environmental differences between the two studies or in the number of animals tested and measurements made.

For the duration of the trial, the calves on 3S1H cows were heavier ($P < .05$) than calves on HH and AH cows but not heavier than calves on 1S1H cows. For all the breed types, calves gained a significant amount of weight from periods 1 to 4.

The two groups of 24 cows used during the study were different in body weight and calf weight but not in milk production. The group means (group 1, group 2) were 570 and 598 kg for body weight; 180 and 172 kg for calf weight; and 9.0 and 8.0 kg/d for milk production. The difference in body weight between the two groups of cows was mainly due to the 3S1H cows in group 2 being 86 kg heavier ($P < .01$) than the 3S1H cows in group 1. For all breed types, calves in group 1 were heavier ($P < .01$) than the calves in group 2.

Daily Grazing Hours

The least-squares analysis of variance for daily grazing hours is presented in table 4. Significant sources of variation included group, cow(breed x group), period(group), day(group x period) and breed type x period(group).

The overall daily grazing mean was 9.4 hr/d with a standard deviation of 1.08 hr/d (633 observations). For lactating cows grazing summer rangeland, Dwyer (1961) and Nelson and Furr (1966) found similar estimates of 9.7 and 10.0 hr/d, respectively, while Gonzalez (1964) found a slightly higher estimate of 10.6 hr/d.

No significant differences, in daily grazing hours, were found between the four breed types used in this study. The overall breed

Table 4. Least-squares analysis of variance for daily grazing hours

Source	df	Mean squares
		Daily grazing hours (hr ² /d ²)
Breed type	3	4.8
Group	1	103.1**
Cow(breed x group)	40	7.8**
Period(group)	2	92.4**
Day(group x period)	28	2.4**
Breed x period(group)	6	2.8*
Residual	549	1.2
R ²		0.54

* P<.05

** P<.01

type means and standard errors were $9.2 \pm .09$, $9.6 \pm .09$, $9.2 \pm .10$ and $9.3 \pm .09$ hr/d for HH, AH, 1S1H and 3S1H cows, respectively. Kropp et al. (1973) also found no differences in daily grazing time between Hereford, Holstein and Hereford x Holstein non-lactating heifers grazing native range but, Stricklin et al. (1976) found significant differences between lactating Angus and Charolais x Angus cows grazing small alfalfa-orchard-grass pastures. It seems that breed type differences, in the amount of time spent foraging for food, are dependent upon the type of forage being consumed. On rangeland, animals with lower energy demands can graze more selectively and thus have lower intake rates than animals with higher energy demands.

Because two groups of cows were used during the study, comparisons of the period means can only be made between periods 1 vs. 3 and 2 vs. 4. Grazing hours significantly increased ($P < .01$) from periods 1 to 3 and from 2 to 4. The daily grazing hours were 8.0 and 9.8 hr/d for periods 1 and 3, respectively, and 9.5 and 10.0 hr/d for periods 2 and 4, respectively.

The increases in grazing time between periods is likely due to decreases in forage quality and quantity (Arnold, 1960; Allden and Whittaker, 1970; Arnold and Dudzinski, 1978). In Utah, Scarnecchia et al. (1985) found grazing times on crested wheatgrass pastures to increase from 6.3 to 10.9 hr/d when forage availability decreased from 919 to 144 kg DM/ha. Although forage availability was not measured in this study, the stocking rate of 1.0 ha/AUM should have significantly depleted the forage resource.

The interaction between breed and period(group) is presented in

table 5. All breed types significantly increased in grazing time from periods 1 to 3 and all breed types except AH increased from periods 2 to 4. AH cows grazed longer ($P < .05$) than HH and 3S1H cows in period 2 and longer than HH, 1S1H and 3S1H cows in period 3. In period 4, the 3S1H cows grazed longer than all the other breed types. It appears that the AH cows responded differently than the other breed types to changes in forage conditions. Because of unequal distribution of grazing on rangeland, forage availability is highly variable from one area to another. Differences between breed types during a particular grazing period could be attributed to the differences in the distribution of grazing. In this case, grazing time is probably dependent upon the forage quality and quantity in the areas they are grazing and the degree of selectivity being expressed.

The residual correlations, between the grazing behavior variables and the cow and calf traits measured in this study, are presented in table 13 (appendix). To determine the effect of the cow body weight, cow milk production, calf weight, calf age and cow condition on daily grazing hours, several analyses were made to avoid the use of any two highly correlated independent variables. Cow body weight was highly correlated with cow condition (.89) and calf weight was highly correlated with calf age (.71).

Of the five cow and calf traits used as covariates in the daily grazing model, only cow milk production and calf age had a significant influence on daily grazing hours (table 6). When age of calf and cow body weight were included in the model, an increase of one kg/d above the mean level of milk production (8.5 kg/d) caused a $.05 \pm .03$ hr/d

Table 5. Least-square means and standard errors for daily grazing hours (hr/d) of the interaction between breed and period(group)^b

Breed ^a Type	Group			
	2		1	
	1	Period 3	2	Period 4
HH	8.3 ± .17 ^c (48)	9.9 ± .15 ^{ef} (48)	9.1 ± .17 ^c (41)	9.7 ± .21 ^f (31)
AH	8.1 ± .21 ^c (31)	10.4 ± .16 ^g (46)	10.0 ± .20 ^{de} (34)	10.0 ± .17 ^{ef} (43)
1S1H	8.0 ± .24 ^c (32)	9.1 ± .24 ^d (30)	9.5 ± .20 ^{ee} (36)	10.0 ± .17 ^f (43)
3S1H	7.9 ± .19 ^c (39)	9.7 ± .17 ^{df} (44)	9.4 ± .16 ^c (47)	10.4 ± .18 ^h (40)

^a Refer to footnote in table 3.

^b Means in rows and columns (within group) with different superscripts are different (P<.05). Number of observations in parenthesis.

Table 6. Effects of covariates on daily grazing hours

Covariate	Partial regression coefficient
Age of calf	-.02 hr/d/d**
Milk production	.05 hr/d/kg/d*
Cow body weight	-.003 hr/d/kg
Cow condition (wt/ht)	-.12 hr/d/kg/cm
Calf weight	-.003 hr/d/kg

* P<.05

** P<.01

increase in daily grazing hours. Thus, more time grazing is required to support the energy costs associated with increased levels of milk production. Using .67 kcal/hr as the energy cost of grazing (Holmes, 1978), the increase in the animal's maintenance requirement would only be .04 kcal/kg of milk produced. Therefore, the influence milk production has on the energy cost of grazing is minimal. Also, for every one day increase above the average calf age (105 d), daily grazing hours decreased by $.02 \pm .01$ hr/d (P<.01). The negative effect of calf age could possibly be due to the cows stage of lactation. Cows with older calves were in a later stage of lactation and produced less milk than cows with younger calves.

Considering all the independent variables together, age of calf had the most important influence on daily grazing hours. The standard partial regression coefficients for age of calf, milk production, cow body weight, cow condition and calf weight were -.07, .06, -.04, -.01

and $-.01$, respectively. Stricklin et al. (1976) found similar relationships between cow weight and calf weight and daily grazing hours however; calf age was not a significant source of variation and the partial correlation was positive (.23). Stricklin's study was conducted on small pastures during May and June with young calves. Under these conditions, the stage of lactation may not be as important as observed in this study.

Time of Day Grazing

The least-squares analyses of variance for the time of day grazing took place are presented in tables 7 and 8. As with daily grazing hours, cow and day were important sources of variation in time of day grazing. Breed type was significant during the 900-1200 hr time period and period(group) was significant in almost all of the 3-hr time periods studied. The interaction between breed and period(group) was important ($P < .05$) during 300-600 and 1800-2100 hr.

The overall time of day grazing means are presented in figure 2. The majority of grazing took place between 600-900 and 1800-2400 hr. Secondary periods of grazing ranging from .5 (2400-300 hr) to .9 hr (1500-1800 hr) were recorded.

A similar pattern of grazing activity was observed by Nelson and Furr (1966) using lactating cows and Kropp et al (1973) using heifers on summer rangeland in Oklahoma. Also using lactating cows in Oklahoma, Dwyer (1961) found similar results with respect to the major grazing periods, but cows in their study grazed more in the early morning and less during the afternoon than the cows used in this study.

Table 7. Least-squares analyses of variance for time of day grazing (2400-1200 hr).

Source	df	Mean squares			
		Time of day grazing (hr ²)			
		Time of Day (x 100 hr)			
		24-3	3-6	6-9	9-12
Breed type	3	6	75	93	153 ⁺
Group	1	339 [*]	81	714 ^{**}	1191 ^{**}
Cow(breed x group)	40	53 ^{**}	94 ^{**}	90 ^{**}	65 ^{**}
Period(group)	2	240 ^{**}	299 ^{**}	748 ^{**}	757 ^{**}
Day(group x period)	28	54 [*]	77 ^{**}	62 ^{**}	88 ^{**}
Breed x period(group)	6	23	68 [*]	51	12
Residual	549	31	25	30	34
R ²		0.22	0.35	0.35	0.30

+ P<.10

* P<.05

** P<.01

Table 8. Least-square analyses of variance for time of day grazing (1200-2400 hr).

Source	df	Mean squares			
		Time of day grazing (hr ²)			
		Time of day (x 100)			
		12-15	15-18	18-21	21-24
Breed type	3	100	31	119	20
Group	1	83	528*	302	710*
Cow(breed x group)	40	103**	116**	155**	123**
Period(group)	2	175*	18	924**	136+
Day(group x period)	28	78*	127**	73**	163**
Breed x period(group)	6	92+	82+	178**	96+
Residual	549	47	45	35	49
R ²		0.22	0.29	0.39	0.29

+ P<.10

* P<.05

** P<.01

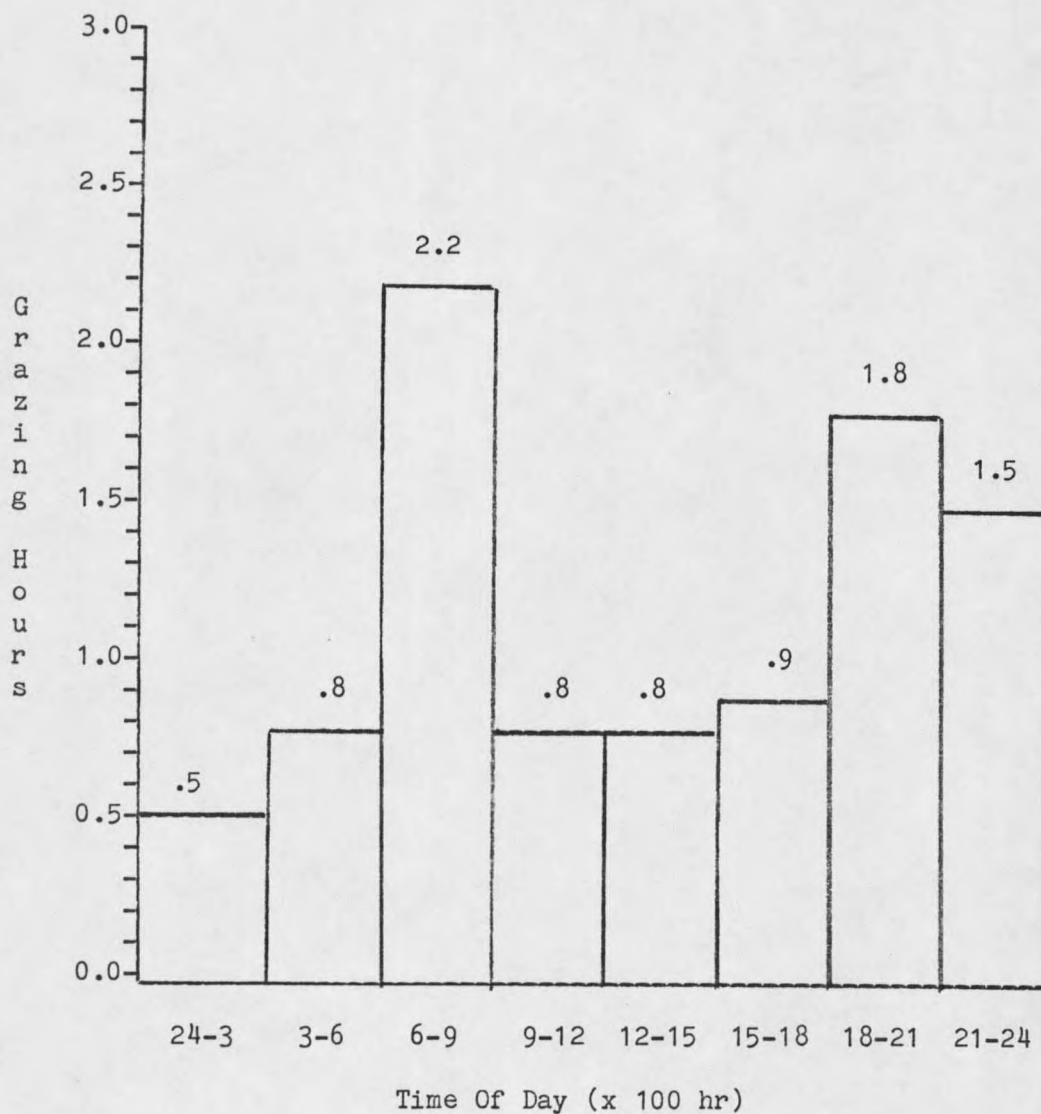


Figure 2. Overall time of day grazing means.

Between 900-1200 hr, the AH cows grazed longer ($P < .05$) than all the other breed types. Breed type means and standard errors for HH, AH, 1S1H and 3S1H cows were $.8 \pm .05$, $.9 \pm .05$, $.7 \pm .05$ and $.8 \pm .05$ hr, respectively. Because there was no significant breed type x period(group) interaction during this time period, this relationship held true during all four of the grazing periods. The longer grazing

times recorded by the AH cows during 900-1200 hr would account for the longer grazing times recorded for the AH cows during grazing periods 2 and 3.

From periods 1 to 3 (group 2), significant increases in grazing time were found for four out of the eight 3-hr time periods (table 9). Grazing time remained fairly constant between 300-600 hr and between 1500-2400 hr and significantly increased during all other time periods.

Table 9. Least-squares means for time of day grazing (hr)^a

Time	Group				Mean Temp. (C)
	2		1		
	Period 1	3	Period 2	4	
2400-0300	0.3 ^b	0.6 ^c	0.6 ^b	0.6 ^b	--
0300-0600	0.8 ^b	0.8 ^b	0.9 ^b	0.6 ^c	19
0600-0900	1.8 ^b	2.3 ^c	2.3 ^b	2.4 ^b	20
0900-1200	0.5 ^b	0.8 ^c	0.8 ^b	1.1 ^c	24
1200-1500	0.6 ^b	0.9 ^c	0.8 ^b	0.9 ^b	26
1500-1800	1.0 ^b	0.9 ^b	0.7 ^b	0.7 ^b	28
1800-2100	1.7 ^b	1.8 ^b	1.6 ^b	2.1 ^c	26
2100-2400	1.3 ^b	1.5 ^b	1.7 ^b	1.6 ^b	25

^a Means in rows, within group, with different superscripts are different (P<.01).

From periods 2 to 4 (group 1), significant increases in grazing time occurred for only two of the eight 3-hr time periods. Grazing time increased ($P < .01$) between 900-1200 and 1800-2100 hr and decreased ($P < .01$) between 300-600 hr. No significant differences were found during the other time periods.

The choice of time period to increase grazing time and the length of time spent grazing is influenced most by forage quality and quantity and weather (Arnold and Dudzinski, 1978). Arnold (1962) found that varying the stocking rate had little effect upon the diurnal pattern of grazing. The major grazing periods remained the same, but with a shortage of feed animals rest less often and so have fewer and longer periods of grazing. Dwyer (1961) observed that during daylight hours, temperature dictated the time of arrival and the length of stay at water. During the present study, the major grazing periods also remained the same throughout the grazing period and no increases in grazing time were found between 1500 and 1800 hr, the warmest time period of the day (table 9).

The interaction between breed and period(group) during 300-600 hr and 1800-2100 hr is presented in table 10. The interactions during these two time periods was mainly due to fluctuations in grazing by the 1S1H cows. From periods 1 to 3, the 1S1H cows increased ($P < .05$) in grazing time between 300-600 hr while the HH and AH cows slightly decreased. Between 1800-2100 hr, the 1S1H cows decreased ($P < .01$) in grazing time while the other breed types increased. From periods 2 to 4, the 1S1H and 3S1H cows decreased ($P < .05$) in grazing time between 300-600 hr while the HH and AH cows slightly decreased. Between 1800-

Table 10. Least-square means for time of day grazing (0300-0600 and 1800-2100 hr) for the interaction between breed type and period(group)^b

Time Period	Breed Type ^a	Group			
		2		1	
		1	3	2	4
0300-0600	HH	0.8 ^c	0.6 ^c	0.7 ^c	0.6 ^{ce}
	AH	0.8 ^c	0.7 ^c	0.7 ^c	0.5 ^{ce}
	1S1H	0.7 ^c	1.1 ^d	0.9 ^{cd}	0.7 ^e
	3S1H	0.8 ^c	0.8 ^c	1.0 ^d	0.5 ^e
1800-2100	HH	1.6 ^c	2.1 ^d	1.8 ^c	2.3 ^d
	AH	1.6 ^c	2.0 ^d	1.5 ^c	1.9 ^e
	1S1H	1.8 ^c	1.2 ^e	1.8 ^c	2.0 ^{de}
	3S1H	1.6 ^c	1.9 ^d	1.5 ^c	2.3 ^d

^a Refer to footnote in table 3.

^b Means in rows and columns (within group and time period) with different superscripts are different; 0300-0600 hr (P<.05), 1800-2100 hr (P<.01).

2100 hr, the 1S1H cows only slightly increased while the other breed types significantly increased. Kropp et al (1973) also found differences in the time of day that grazing took place for Hereford, Holstein and Hereford x Holstein heifers. During July and August, Holstein heifers grazed longer in the evening than Hereford and Hereford x Holstein heifers and Hereford x Holstein heifers grazed longer than Hereford and Holstein heifers in the afternoon. Why these differences existed was not known. Differences between breeds during particular time periods could be attributed to differences in response to changes in weather patterns and forage availability.

Because milk production and age of calf had an important influence on daily grazing hours, they were included, along with cow body weight, in each of the time of day grazing models. The residual correlations between time of day grazing and the cow and calf variables are presented in table 13 (appendix).

The effect of milk production was mainly expressed ($P < .05$) between 2400-300, 600-900 and 1500-1800 hr. The partial regression coefficients for milk production were $.03 \pm .01$, $-.03 \pm .01$ and $.03 \pm 0.01$ hr/d/kg/d for 2400-300, 600-900 and 1500-1800 hr, respectively. The level of milk production had its strongest influence ($P < .01$) between 2400-300 hr. This would agree with Stobbs (1975) who reported the tendency for higher milking cows to graze more at night. The effect of calf age was mainly expressed ($P < .05$) between 300-600 and 1800-2100 hr. The partial regression coefficients were $.01 \pm .004$ and $-.01 \pm .005$ hr/d of calf age for 300-600 and 1800-2100 hr, respectively.

Stricklin et al. (1976) found cow body weight as a significant source of variation in explaining total night hours spent grazing. The partial correlation (-.20) was negative, indicating that smaller cows grazed more at night. In this study, cow body weight was important ($P < .01$) source of variation in grazing time between 1800-2100 hr, but the partial regression coefficient (.005 hr/kg) was so low that it was biologically unimportant.

Distance Traveled

The least-squares analysis of variance for distance traveled is presented in table 11. Breed type, period(group), sex of calf and breed type x sire breed of calf were significant sources of variation in distance traveled.

The overall mean and standard deviation for distance traveled was 4.7 ± 0.9 km/d (82 observations). The breed type means and standard errors were $5.0 \pm .2$, $4.8 \pm .2$, $4.1 \pm .2$ and $4.8 \pm .2$ km/d for HH, AH, 1S1H and 3S1H cows, respectively. 1S1H cows traveled less than ($P < .05$) HH, AH and 3S1H cows and this relationship held true during three of the four grazing periods. Because the pedometers were not calibrated for length of stride differences between the four breed types, it is possible that the breed type differences, in distance traveled, are due to differences in length of stride. Breed type means for cow height were 129, 129, 134 and 135 cm for HH, AH, 1S1H and 3S1H cows, respectively. The Simmental cross cows (1S1H and 3S1H) were taller ($P < .05$) than the HH and AH cows and could have a longer stride than HH and AH cows however, the raw correlation between cow height and the distance traveled was only -.04.

Table 11. Least-squares analysis of variance for distance traveled

Source	df	Mean squares
		Distance traveled (km ² /d ²)
Breed type (B)	3	26.6*
Group (G)	1	1.1
Period(Group) (P/G)	2	28.0*
Sex of calf (Sx)	1	89.7**
Sire breed of calf (S)	1	11.1
B x P/G	9	12.3
B x S	3	17.0 ⁺
Regression		
Age of calf	1	0.0
Residual	60	7.5
R ²		0.33

⁺ P<.10

^{*} P<.05

^{**} P<.01

The distance traveled values reported here are similar to those reported by Gonzalez (1964) and Dwyer (1961) of 4.0 and 5.0 km/d, respectively, for cows grazing on a similar size pasture but less than those reported by Herbel and Nelson (1966) for Hereford (6.9 km/d) and Santa Gertrudis (14.6 km/d) cows grazing on a 1464 ha pasture.

Distance traveled increased (P<.05) from 4.3 to 5.0 km/d from period 1 to period 3 and remained fairly constant from periods 2 to 4

(4.6 and 4.9 km/d, respectively). From period 1 through 4, distance traveled followed the same general trend as daily grazing hours. Two hr/d were spent grazing for every km/d of travel in all four of the grazing periods.

Cows with steer calves traveled farther ($P < .01$) than cows with heifer calves and this relationship held true for all breed types across all periods. Sex means were 4.3 and 5.0 km/d for cows with heifer and steer calves, respectively.

When all of the cow and calf traits were used as covariates in the distance traveled model, only cow condition came close to having any effect on distance traveled ($P < .20$).

Why calf sex was important in explaining the variation in distance traveled is not clearly understood. Calf sex remained significant when calf age, calf weight, cow weight, milk production and cow condition were used in the model.

Distribution of Grazing

The least-squares analysis of variance table for distribution of grazing is presented in table 12. The number of observations/cow used to calculate distribution ranged from 16 to 22 and were recorded during grazing periods 1, 2 and 4. Of the five cow and calf traits used as continuous independent variables, only calf weight had any significant influence on distribution of grazing.

The mean and standard deviation for distribution of grazing was 103 ± 36 ha/cow. The proportion of the pasture covered by each of the 47 cows used in the analysis ranged from 21 to 44%. Gillen (1983), estimating the home range behavior of lactating cows in Oregon, found

Table 12. Least-squares analysis of variance for distribution of grazing

Source	df	Mean squares
		Distribution (ha ²)
Breed type	3	820
Sex of calf	1	92
Sire breed of calf	1	1638
Regressions		
No. observations	1	497
Calf weight	1	5867*
Cow condition	1	1136
Residual	38	1309
R ²		0.21

* P<.05

that cows had a home range of 343 ha (17 observations) in a 3610 ha pasture. The larger area observed by Gillen could be due to a smaller number of observations, a larger pasture size and differences in pasture topography. Increasing the number of observations decreases the estimated area (Gillen, 1983) and animals in larger pastures travel farther distances than animals in smaller pastures (Anderson and Kothmann, 1980).

There was no difference between the four breed types in the distribution of grazing. The distribution means were 105 ± 11, 115 ± 11, 93 ± 11 and 99 ± 11 ha/cow for HH, AH, 1S1H and 3S1H,

respectively. Gillen (1983) also observed no differences in home range size between purebred (Hereford, Angus, Red Angus) and crossbred (Hereford x Angus, Hereford x Red Angus) cows.

The partial regression coefficient for calf weight was $.5 \pm .2$ ha/kg. Within each breed type, cows with calves above average in weight covered a greater area of the pasture than cows with calves below average in weight (adjusted for cow condition).

The reason why calf weight was important to distribution of grazing is probably due to the ability of the calf to travel. The heavier calf is in better condition to travel with its mother to a greater variety of grazing areas. Although calf age explained a significant amount of the variation in calf weight, calf age was not as important as calf weight to distribution of grazing. The reason why calf weight was not significant in explaining the variation in distance traveled is probably because the calf is not required to travel the same distance as the cow. The distance a cow travels can be a combination of movement while grazing, movement between grazing areas and movement between water and grazing areas while the calf needs only to travel with its mother from one grazing area to another.

Although cow condition was not significant in explaining the variation in both the distribution and distance traveled models, it seems to be an important factor influencing animal movement. Cows in good condition are able to travel longer distances and see a greater proportion of the pasture than cows in poor condition.

To examine how distribution of grazing influenced cow and calf

performance during the grazing season, the change in body weight and milk production, along with calf average daily gain, were analyzed using distribution of grazing and age of calf as covariates.

The overall change in body weight mean was 2.4 kg (range = -12.1 to 17.9 kg) during the grazing season. 20% of the variation (within breed type) in the gain or loss in cow body weight could be explained by the area of the pastured covered during the grazing season. For every hectare increase above the average distribution of grazing (103 ha), cows gained $.3 \pm .07$ kg ($P < .01$) in body weight (adjusting for age of calf). Animals that utilized a greater proportion of the pasture probably grazed in areas where forage was of better quality than those animals that confined themselves to a smaller proportion of the pasture.

Distribution of grazing had no influence on calf average daily gain or the change in milk production. Although cows with heavier calves had a larger grazing distribution than cows with smaller calves, the travel did not seem to affect the gain of the calf and the benefits received by increased distribution of grazing were utilized for weight gain and not milk production.

Speculation and Future Direction

The overall objective, of this study, was to determine if there are any differences in energy expenditure between four genotypically different types of beef cattle grazing rangeland. To accomplish this objective, the grazing behavior variables chosen to measure were time spent grazing, distance traveled and distribution of grazing.

No differences were found in the amount of amount of time spent

grazing between HH, AH, 1S1H and 3S1H lactating cows. From this information, it is difficult to determine if energy expenditure differences exist between these four breed types. Because time spent grazing includes time spent eating and time spent foraging, the energy cost of grazing includes the energy cost of eating plus the energy costs associated with both horizontal and vertical movement while grazing. That proportion of the daily energy expenditure, due to the energy costs of grazing, could be different between these breed types depending upon how far and on what slope the animal traveled while grazing. In this study, measurement of distribution of grazing was an attempt to identify breed type differences in area utilization. However, an estimation of area utilization does not indicate how these breed types may differ in utilization of sloping terrain.

The level of forage intake (kg/d) is equal to the amount of time spent grazing (hr/d) multiplied times the rate of forage intake (kg/hr). Because intake differences have been reported between these same breed types (Wagner, 1985; Kronberg, 1983), differences in the rate of forage intake could possibly exist. Intake rate is the product of bite rate (bites/hr) and bite size (kg/bite). Measurement of these variables would be a decisive step in determining where the differences in grazing behavior exist between these breed types.

During this study, 1S1H cows traveled .9 km/d less than HH cows and .7 km/d less than HH and AH cows. It is difficult to determine if these differences would translate into energy expenditure differences or not. Breed type differences in energy expenditure can not be detected unless some measurement of the slope of the terrain, over

which the animal traveled, is known.

The distance an animal travels can be a combination of movement while grazing, movement between grazing areas and movement between water and grazing areas. In this study, 1S1H cows traveled less distance ($P < .05$) yet covered the same area of the pasture ($P > .10$) as the other three breed types. It is possible that 1S1H cows demonstrate some differences in animal movement. One possible difference could be in frequency of drinking. Certain animals, grazing in areas far from water, were observed to drink less frequently. By drinking less frequently, animals can conserve energy and maximize pasture utilization.

At the present time, it can not be determined if there are or are not breed type differences in energy expenditure. Future studies, measuring the grazing behavior of cows grazing rangeland, should include some estimation of forage intake rate, slope utilization and frequency of drinking.

Wagner (1985), using the group 1 cows from this study (in an adjacent pasture), found significant intake differences between the four breed types. The overall intake means were 2.3, 2.5, 2.6 and 2.8% BW/d for HH, AH, 1S1H and 3S1H cows, respectively. HH cows consumed less forage ($P < .07$) than both the 1S1H and 3S1H cows but not less than the AH cows. At the present time, it is difficult to assume that the breed type differences in intake observed by Wagner would exist under the conditions of this study. Because of the many factors influencing grazing behavior (Arnold and Dudzinski, 1978), the level of energy expenditure can change from one environment to another. Under the

conditions of Wagner's study, animals were gathered on a daily basis and the natural behavior patterns were interrupted. How this affected time spent grazing, distance traveled and pasture utilization is not known. Future studies should examine how the experimental methods, used in estimating animal intake, influence animal grazing behavior.

SUMMARY

The grazing behavior of lactating beef cows grazing rangeland was studied during the summer of 1984 in the Bear Paw Mountains near Havre Montana. A total of 48 cows were divided into two groups. Each group contained six cows from the following four breed types: straight Hereford (HH), 50% Angus-50% Hereford (AH), 50% Simmental-50% Hereford (1S1H) and 75% Simmental-25% Hereford (3S1H). The study consisted of four grazing periods starting on July 22 and ending on August 30.

The grazing behavior variables included daily grazing hours, time of day grazing, distance traveled and distribution of grazing. The basic model for analysis of the grazing behavior variables included breed type, group, period(group), sex of calf and sire breed of calf as fixed main effects and breed type by period(group) as the main interaction. Additions to the daily grazing and time of day grazing models included cow (random) and day (fixed). Cow weight, cow milk production, cow condition, calf weight and age of calf were used as covariates whenever possible to examine their effects on cow grazing behavior.

The overall daily grazing mean was 9.4 hr/d. Grazing time increased from 8.0 (period 1) to 10.0 hr/d (period 4) during the 40-d grazing season. No difference in daily grazing hours was found between the four breed types. Age of the calf and level of milk production were the most important ($P < .05$) covariates explaining the variation in daily grazing hours. The partial regression coefficients for calf age

and milk production were $-.02$ hr/d/d and $.05$ hr/d/kg/d, respectively.

The majority of grazing took place between 600-900 and 1800-2400 hr. AH cows grazed longer ($P<.05$) between 900-1200 hr than all of the other breed types. From periods 1 to 4, increases in grazing time were recorded during five of the eight 3-hr daily time periods. Grazing time decreased between 300-600 hr and remained fairly constant between 1500-1800 and 2100-2400 hr. The influence of milk production on time spent grazing was mainly found between 2400-300 hr.

The overall mean distance traveled was 4.7 km/d. Breed type was a significant source of variation in distance traveled. Breed type means were 5.0, 4.8, 4.1 and 4.8 km/d for HH, AH, 1S1H and 3S1H cows, respectively. 1S1H cows traveled less than ($P<.05$) HH, AH and 3S1H cows. Cows increased in distance traveled from 4.3 to 4.9 km/d from periods 1 to 4 and this increase followed the same general trend as daily grazing hours. Two hr/d were spent grazing for every kilometer of travel in all four of the grazing periods.

The overall distribution mean was 103 ha/cow. The proportion of the pasture covered by each cow ranged from 21 to 44%. No difference in distribution of grazing was found among the four breed types. Calf weight explained a significant amount of the variation in distribution of grazing. Cows with calves above average in weight covered a greater proportion of the pasture (0.5 ha/kg) than cows with calves below average in weight (adjusted for cow body condition).

Distribution of grazing did not influence the change in cow milk production or calf average daily gain but did significantly affect the cow's change in body weight. Cows gained 0.3 kg in body weight for

every hectare increase above the average distribution of grazing.

From the results presented here, a significant amount of the variation (within a breed type) in grazing behavior can be attributed to a variety of characteristics associated with the cow and the calf. Between breed types, there seems to be no association between a breed type's energy requirements and any of the grazing behavior variables measured in this study. The breed type with the smallest energy requirement (HH) spent the same amount of time grazing, traveled the same distances and cover the same area of the pasture as the breed type with the largest energy requirement (3S1H). This would indicate that the increase in the maintenance requirement, due to the energy cost of grazing and travel, was the same across the four breed types. However, energy expenditure differences among these breed types could not be determined because the slope of the terrain over which the animals travel was not measured.

LITERATURE CITED

LITERATURE CITED

- Allden, W. G. and I. A. McD. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. Aust. J. Agr. Res. 21:755.
- Anderson, D. M. and M. M. Kothmann. 1977. Monitoring animal travel with digital pedometers. J. Range Mgt. 30:316.
- Anderson, D. M. and M. M. Kothmann. 1980. Relationship of distance traveled with diet and weather for Hereford heifers. J. Range Mgt. 33:217.
- Arnold, G. W. 1960. The effect of quantity and quality of pasture available to sheep on their grazing behavior. Aust. J. Agr. Res. 11:1034.
- Arnold, G. W. 1962. The influence of several factors in determining the grazing behavior of Border Leicester x Merino sheep. J. Brit. Grassl. Soc. 17:41.
- Arnold, G. W. 1964. Factors within plant associations affecting the behavior and performance of grazing animals. In: D. J. Crisp (ed), Grazing in Terrestrial and Marine Environments. Blackwell, Oxford.
- Arnold, G. W. 1975. Herbage intake and grazing behavior in ewes of four breeds at different physiological states. Aust. J. Agr. Res. 26:1017.
- Arnold, G. W. and H. A. Birrell. 1977. Food intake and grazing behavior of sheep varying in body condition. Anim. Prod. 24:343
- Arnold, G. W. and M. L. Dudzinski. 1967. Studies on the diet of the grazing animal. II. The effect of physiological status in ewes and pasture availability on herbage intake. Aust. J. Agr. Res. 18:349.
- Arnold, G. W. and M. L. Dudzinski. 1978. Ecology of Free-Ranging Domestic Animals. Elsevier Scientific Publishing Co., Amsterdam.
- Blaxter, K. L. 1962. The Energy Metabolism of Ruminants. Hutchinson Scientific and Technical, London. 329 p.

- Brumby, P. J. 1959. The grazing behavior of dairy cattle in relation to milk production, live weight and pasture intake. NZ. J. Agr. Res. 2:797.
- Casebolt, D. G. 1984. Lactation curves and milk production in cattle with varying degrees of crossbred influence. Master Thesis, Montana State University, Bozeman.
- Chacon, E. and T. H. Stobbs. 1976. Influence of progressive defoliation of a grass sward on the eating behavior of cattle. Aust. J. Agr. Res. 27:709.
- Clapperton, J. L. 1964. The energy metabolism of sheep walking on the level and on gradients. Brit. J. Nutr. 18:47.
- Cook, C. W. and L. E. Harris. 1968. Nutritive value of seasonal ranges. Utah State Univ. Exp. Sta. Bull. 477. 55 p.
- Cook, C. W. 1966. Factors affecting utilization of mountain slopes by cattle. J. Range Mgt. 19:200.
- Dunn, T. G., M. L. Riley, W. J. Murdoch and R. A. Field. 1983. Body condition score and carcass energy content in postpartum beef cows. Proc. West. Sec., Amer. Soc. Anim. Sci. 34:56.
- Dwyer, D. D. 1961. Activities and grazing preferences of cows with calves in northern Osage County Oklahoma. Okla. Agr. Exp. Sta. Bull. B-588. 61 p.
- Gary, L. A., G. W. Sherritt and E. B. Hale. 1970. Behavior of Charolais cattle on pasture. J. Anim. Sci. 30:203.
- Gillen, R. L. 1983. Grazing behavior and distribution of cattle on mountain rangelands. Ph.D. diss., Oregon State University, Corvallis.
- Gillen, R. L., W. C. Krueger and R. F. Miller. 1984. Cattle distribution on mountain rangeland in northeastern Oregon. J. Range Mgt. 37:549.
- Gonzalez, M. H. 1964. Patterns of livestock behavior and forage utilization as influenced by environmental factors on a summer mountain range. Ph.D. diss., Utah State University, Logan.
- Graham, N. McC. 1964. Energy costs of feeding activities and energy expenditure of grazing sheep. Aust. J. Agr. Res. 15:969.
- Hancock, J. 1954. Studies of grazing behavior in relation to grassland management. I. Variations in grazing habits of dairy cattle. J. Agr. Sci. 44:420.

- Havstad, K. M. and J. C. Malechek. 1982. Energy expenditure by heifers grazing crested wheatgrass of diminishing availability. *J. Range Mgt.* 35:447.
- Havstad, K. M., A. S. Nastis and J. C. Malechek. 1983. The voluntary forage intake of heifers grazing a diminishing supply of crested wheatgrass. *J. Anim. Sci.* 56:259.
- Hayne, D. W. 1949. Calculation of size of home range. *J. Mammal.* 30:1.
- Hedrick, D. W., J. A. Young, J. A. B. McArthur and R. F. Keniston. 1968. Effects of forest and grazing practices on mixed coniferous forests of northeastern Oregon. *Oregon Agr. Exp. Sta. Bull.* 103. 24 p.
- Hendricksen, R. and D. J. Minson. 1980. The feed intake and grazing behavior of cattle grazing a crop of *Lablab purpureus* cv. Rongai. *J. Agr. Sci.* 95:547.
- Herbel, C. H. and A. B. Nelson. 1966. Activities of Hereford and Santa Gertrudis cattle on a southern New Mexico range. *J. Range Mgt.* 19:173.
- Holmes, C. W., N. A. McLean and K. J. Lockyer. 1978. Changes in the rate of heat production of calves during grazing and eating. *N.Z. J. Agr. Res.* 21:107.
- Johnstone-Wallace, D. B. and K. Kennedy. 1944. Grazing management practices and their relationship to the behavior and grazing habits of cattle. *J. Agr. Sci.* 34:190.
- Kleiber, M. 1965. Metabolic body size. In: *Energy Metabolism*. K. L. Blaxter (ed.). Academic Press Inc., New York. 450 p.
- Kothmann, M. M. 1980. Chapter 6, Part A. Nutrition of livestock grazing range and pasture lands. In: *Digestive Physiology and Nutrition of Ruminants*. D. C. Church (ed.). Volume 3, Practical Nutrition. O & B Books, Inc., Corvallis, Oregon. 416 p.
- Kress, D. D., D. E. Doornbos, D. C. Anderson and D. D. Trowbridge. 1984a. Productivity of two-year old straightbred and crossbred dams. I. Calf performance. *Proc. West. Sec., Amer. Soc. Anim. Sci.* 35:86.
- Kress, D. D., D. E. Doornbos, D. C. Anderson and D. D. Trowbridge. 1984b. Productivity of two-year old straightbred and crossbred dams. II. Dam performance and overall productivity. *Proc. West. Sec., Amer. Soc. Anim. Sci.* 35:90.

- Kress, D. D., D. E. Doornbos and D. C. Anderson. 1985. Performance of calves raised on straightbred and crossbred beef dams. *J. Anim. Sci.* 61 (Supp. 1):231.
- Kronberg, S. L., 1983. Forage intake of Hereford and 75% Simmental-25% Hereford cow grazing Montana foothill rangeland. Master Thesis, Montana State University, Bozeman.
- Kropp, J. R., J. W. Holloway, D. F. Stephens, L. Knori, R. D. Morrison and R. Totusek. 1973. Range behavior of Hereford, Hereford x Holstein and Holstein non-lactating heifers. *J. Anim. Sci.* 36:797.
- Lofgreen, G.P. and W. N. Garrett. 1968. A system for expressing net energy requirements and feed values for growing and finishing beef cattle. *J. Anim. Sci.* 27:793.
- Malechek, J. C. and B. M. Smith. 1976. Behavior of range cows in response to winter weather. *J. Range Mgt.* 29:9.
- Mueggler, W. F. 1965. Cattle distribution on steep slopes. *J. Range Mgt.* 18:255.
- Nastis, A. S. 1979. Effects of forage availability on voluntary intake and feeding behavior of grazing heifers. Ph.D. diss. Utah State University, Logan.
- National Research Council (NRC), 1984. Nutrient Requirements of Beef Cattle. 6th Revised Ed. National Academy Press, Wash., D. C.
- Nelson, A. B. and R. D. Furr. 1966. Interval of observation of grazing habits of range beef cows. *J. Range Mgt.* 19:26.
- Nutt, B. G., J. W. Holloway and W. T. Butts, Jr. 1980. Relationship of rumen capacity of mature Angus cows to body measurements, animal performance and forage consumption on pasture. *J. Anim. Sci.* 51:1168
- Osuji, P. O. 1974. The Physiology of eating and the energy expenditure of the ruminant at pasture. *J. Range Mgt.* 27:437.
- Peterson, R. A. and E. J. Woolfolk. 1955. Behavior of Hereford cows and calves on short grass range. *J. Range Mgt.* 8:51.
- Purser, D. B. and R. J. Moir. 1966. Rumen volume as a factor involved in individual sheep differences. *J. Anim. Sci.* 25:389.
- Quinn, J. A. and D. F. Hervey. 1970. Trampling losses and travel by cattle on sandhills range. *J. Range Mgt.* 23:50.

- Ribeiro, J. M. de C. R., J. M. Brockway and A. J. F. Webster. 1977. A note on the energy cost of walking in cattle. *Anim. Prod.* 25:107.
- Roath, L. R. and W. C. Krueger. 1982. Cattle grazing and behavior on a forested range. *J. Range Mgt.* 35:332.
- Rutter, N. 1968. Time lapse photographic studies of livestock behavior outdoors on the college farm, Aberystwyth. *J. Agr. Sci.* 71:257.
- SAS Institute Inc. SAS User's Guide: Statistics, 1982 Edition. Cary, NC: SAS Institute Inc., 1982. 584 p.
- Scarnecchia, D. L., A. S. Nastis and J. C. Malechek. 1985. Effects of forage availability on grazing behavior of heifers. *J. Range Mgt.* 38:177.
- Squires, V. R. 1978. Distance trailed to water and livestock response. *Proc., Intern. Rangeland Cong.* 1:431.
- Stobbs, T. H. 1970. Automatic measurement of grazing time by dairy cows on tropical grass and legume pastures. *Trop. Grassl.* 4:237.
- Stobbs, T. H. 1973. The effect of plant structure on the intake of tropical pastures. I. Variation in the bite size of grazing cattle. *Aust. J. Agr. Res.* 24:809.
- Stobbs, T. H. 1975. Factors limiting the nutritional value of grazed tropical pastures for beef and milk production. *Trop. Grassl.* 9:141.
- Stricklin, W. R., L. L. Wilson and H. B. Graves. 1976. Feeding behavior of Angus and Charolais x Angus cows during summer and winter. *J. Anim. Sci.* 43:721.
- Valentine, K. A. 1947. Distance from water as a factor in grazing capacity of rangeland. *J. Forestry.* 45:749.
- Wagner, M. W. 1985. Forage intake and milk production of rangeland beef cows with varying degrees of crossbred influence. Master Thesis, Montana State University, Bozeman.
- Walker, J. W., R. K. Heitschmidt and S. L. Dowhower. 1985. Evaluation of pedometers for measuring distance traveled by cattle on two grazing systems. *J. Range Mgt.* 38:90.
- Warner, A. C. I. and B. D. Stacy. 1968. The fate of water in the rumen. 2. Water balances throughout the feeding cycle in sheep. *Brit. J. Nutr.* 22:389.

- Webster, A. J. F. and D. Valks. 1966. The energy cost of standing in sheep. Proc. Nutr. Soc. 25:22.
- Williams, J. H., D. C. Anderson and D. D. Kress. 1979a. Milk production in Hereford cattle. I. Effects of separation interval on weigh-suckle-weigh milk production estimates. J. Anim. Sci. 49:1438.
- Williams, J. H., D. C. Anderson and D. D. Kress. 1979b. Milk production in Hereford cattle. II. Physical measurements: repeatabilities and relationships with milk production. J. Anim. Sci. 49:1443.
- Yeates, T. M. and D. M. Murray. 1966. Walking trials with cattle. I. A breed comparison in moderate heat. J. Agr. Sci. 67:353.
- Young, B. A. 1966. Energy expenditure and respiratory activity of sheep during feeding. Aust. J. Agr. Res. 17:355.
- Young, B. A. and J. L. Corbett. 1972. Maintenance energy requirements of grazing sheep in relation to herbage availability. I. Calorimetric estimates. Aust. J. Agr. Res. 23:57.

APPENDIX

Table 13. Residual correlations between grazing behavior variables and cow and calf traits^a

Trait	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Daily Grazing Hours (1)	.07	.12	-.15	.18	.02	-.07	-.16	-.19
Distance Traveled (2)		-.02	.22	.06	.09	.13	.19	.22
Distribution (3)			.10	.12	.15	.11	-.17	.01
Cow Body Weight (4)				.11	.34**	.89**	.36*	.34*
Milk Production (5)					.29**	.17	-.06	-.10
Calf Weight (6)						.34**	.71**	.06
Cow Condition (7)							.27	-.12
Age of Calf (8)								.24
Cow Height (9)								

^a The model used for the analysis included; Breed type, Period, Sex of calf and Sire breed of calf as fixed main effects. Variables had different degrees of freedom and significance of each correlation was calculated separately. (* P<.05, ** P<.01).

Table 14. Residual correlations between daily grazing hours and time of day grazing^a

Trait	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Daily Grazing Hours (1)	.39	.16	.15	.16	.26	.14	.22	.37
Time of Day								
2400-300 (2)		-.05	-.27	-.08	.06	.04	-.09	.12
300-600 (3)			-.29	-.34	.14	.13	.00	-.16
600-900 (4)				.12	-.27	-.18	.13	.08
900-1200 (5)					.01	-.24	-.14	-.04
1200-1500 (6)						-.12	-.27	-.17
1500-1800 (7)							-.11	-.27
1800-2100 (8)								-.02
2100-2400 (9)								

^a The model used for the analysis included; Breed type, Period, Sire breed of calf, Sex of calf as fixed main effects. Correlations (absolute values) $\geq .13$ are significant ($P < .05$).

