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THE RELATIONSHIP OF CLIMATIC FACTORS TO GRAZING ACTIVITIES OF COWS ON WINTER AND SPRING RANGES

by

Benton M. Smith

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

of

MASTER OF SCIENCE

in

Range Science

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1973

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A special thanks goes to my dear wife, Lynda, for her support and her persistence in typing this paper.

Benton M. Smith

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ABSTRACT

The Relationship of Climatic Factors to Grazing

Activities of Cows on Winter and Spring Ranges

by

Benton M. Smith, Master of Science

Utah State University, 1973

Major Professor: Dr. John C. Malechek
Department: Range Science

The purpose of this research was to investigate the effects of climatic variations upon the daily activities of grazing cattle. The activities of individual cows on a partially seeded salt desert shrub range were observed and recorded during three grazing periods. Two of the periods were during consecutive winters and the other during the spring. Climatic variations during the second winter period were quantified and compared to changes in the daily activity patterns of the cattle.

Distinctly different daily routines of cattle activities were evident for the winter and spring seasons. In the spring, the cattle grazed, traveled, and drank more each day than they did during the winter months. The increase in these activities was attributed to the more temperate climatic conditions and the higher energy demands of lactation.

Air temperature, changes in barometric pressure, windspeed, precipitation, snow depth, and radiation all influenced cattle activities in the winter. Decreasing air temperature and rapid fluctuations in barometric pressure both correlated significantly with increased grazing time. Increasing windspeed and greater snow depth caused the cattle to travel less distance daily. The cattle ceased grazing during snowstorms. They oriented themselves at right angles to the sun while standing and lying. The modifications which occurred in daily activity patterns were shown to be apparently directed toward the conservation of energy during periods of climatic stress.

(99 pages)

INTRODUCTION

The diurnal and seasonal variations of climatic factors probably exert a profound influence on the behavior and nutritional requirements of range animals. Extremes in climatic variations impose stresses on the animals. These stresses are reflected by changes in the activity patterns of the animals. The exact nature of these changes is not completely understood, however. A better understanding of the animals' activities under climatic stress may be beneficial in interpreting rangeland experiments correctly and in designing management schemes which will result in optimum production by range animals and rangeland pastures.

The majority of the research concerning the influence of climatic stress on range animals has been directed toward heat stress under summer, tropical, or desert conditions. Relatively little work has been done to determine the changes which cold stress imposes upon the activities of range cattle. This study has two major objectives:

1. To establish the daily activity routine of grazing cattle under winter and spring conditions.

2. To determine the role of climatic conditions in causing deviations from this routine.

REVIEW OF LITERATURE

Early Studies and Review Articles on Grazing Behavior

The first recorded observations of the grazing behavior of cattle were apparently made by an Englishman, James Anderson, in 1797. Johnstone-Wallace and Kennedy (1944) state that Anderson developed a pasture rotation system based on the observations he had made of the manner in which cattle utilized grass more efficiently when they were first placed in a pasture. He concluded that forage utilization could be increased by dividing pastures into smaller units and letting all the cattle graze in one unit each day.

One of the first studies in this country was conducted by Shepperd in 1921. He observed cattle in four pastures at 15-minute intervals for one day. He concluded that the cattle in the larger pastures gained less weight because they travelled a greater distance each day.

Cory (1927) observed individual animals from early in the morning until grazing ceased after sundown. He estimated, by counting the number of steps taken, that range cattle travel 5,800 yards per day. He also observed the time spent feeding, salting, watering, resting, ruminating, and idling. From these observations, he determined that the cattle spent 7.75 hours, or 56.46 percent of their active time, grazing each day. He assumed that cattle did not graze during the night.

Tribe (1950) stated in his review that researchers should avoid drawing wide conclusions from single studies of grazing behavior. He emphasized that each study must be considered in relation to the conditions of the particular environment in which it was carried out. He also pointed out that the "how, when, where and why" of grazing behavior is more important than the "for how long." In this connection, Hancock observed:

> The significance of much of the published work on grazing behaviour is difficult to evaluate for the reason that, in general, too few animals were observed on only a limited number of days. In some of the early work only day-time behaviour was noted. (Hancock, 1953, p. 1)

He also mentioned several general conclusions which were evident from early grazing studies: Temperatures in the temperate zone had little effect on grazing time. Wind and rainstorms caused cattle to stop grazing and seek shelter or drift with the wind. When air temperatures exceeded 85° F, daytime grazing was reduced and night grazing increased. Shorter daylength caused an increase in grazing during the night hours. High temperatures, wind, rain, and flies all caused cattle to travel farther during a day's activities. The rates at which an animal ruminates and grazes are inherited characteristics. Cattle drink from one to eight times daily depending on the air temperature and the dry matter content of the forage. Feeding time is not related to the total dry matter intake, but it is related to the quality and quantity of forage available. Ruminating time is a function of the total dry matter intake and the crude fiber content of the ingested forage. An increase in either one results in an increase in the time spent ruminating.

Daily Routine of Cattle Activities

Most researchers agree that cattle follow a regular daily routine divided into periods of grazing, ruminating, standing or lying idle, and drinking. Travel or walking time is largely associated with traveling to and from water (Sneva, 1970). Defecations and urinations occur throughout the day. Smith (1959) stated that the cattle which he studied followed a fixed daily pattern independent of stocking rate, season, and temperature extremes. This pattern consised of morning, afternoon, and night grazing periods, with a daily drink at mid-day. The remainder of the time was spent ruminating or loafing in the shade.

Moorfield and Hopkins (1951) also found that cattle follow a fairly predictable daily routine. Animals in their study arose and commenced grazing at 5:00 to 6:00 a.m. each morning. After grazing steadily for approximately 3 hours, they traveled to water and drank. The time from 9:00 a.m. to 5:00 p.m. was spent loafing with occasional short periods of grazing. The cattle grazed steadily from 5:00 p.m. until shortly after dark, when they bedded down for the night. These cattle spent about 10 hours grazing and traveled from 2.5 to 3.0 miles each day. It was mentioned in another study (Cartwright and Carpenter,

1961) that Hereford and Hereford   Brahman cows nurse their calves at the same times each day. Kropp et al. (1973) also indicated the establishment of a daily routine of cattle activities which was largely unchanged from day to day.

The results of some studies indicate the existence of circadian rhythms in the daily routine. For example, cattle tend to graze in the early morning, evenings, around midnight, and possibly during mid-morning. O'Donnell and Walton (1969) described these as "intense grazing" periods, with "desultory grazing" occurring at irregular intervals throughout the remainder of the day. Distinct early morning and late evening grazing periods were reported by Sneva (1970) in yearling beef cattle. Periods of intensive grazing activity from 4:00 a.m. to 8:00 a.m., from 10:00 a.m. to 12:00 a.m., and from 4:00 p.m. to 8:00 p.m. each day were relatively unaffected by different grazing systems, various mixtures of plant species, or daily temperature variations in a study by Shepperd, Blaser, and Kincaid (1957). Weaver and Tomanek (1951) noted that 67 percent of a herd of cattle could be observed grazing between 4:00 a.m. and 8:00 a.m. each day, while 71 percent were observed grazing between 5:00 p.m. to 9:00 p.m. They estimated that each animal spent approximately 10.5 hours grazing daily.

While it is well-established that a daily routine of cattle activities does exist, it is also evident that this routine is altered, often drastically, by various environmental and animal-related factors. These

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factors will be dealt with separately in the succeeding sections. It will be shown that as pointed out by Hafez (1968), cattle are extremely flexible in terms of adjusting their daily routine to meet changing conditions. Table 1 presents a summary of the amount of time spent in the three major activities (grazing, ruminating, idle) by cattle over 24-hour periods as reported by various researchers. The season and approximate time of day when grazing occurs is given to demonstrate some of the variations which occur in the daily routine under different environmental regimes.

Table 1. The amount of time spent by cattle in the three major activities of grazing, ruminating, and idle over 24-hour periods as reported by eight researchers

Grazing	Ruminating	Idle	Conditions	Time of grazing[a]	Citation
6.0	5.3	9.0	Supplemented	M, E	Gary, Sherritt, and Hale (1970)
7.9	7.8	8.3	Late summer	M, N, E	Pearson-Hughes and Reid (1951)
8.6	6.0	9.4	Summer pasture	M, E, MN	Moran (1970)
8.6	6.1	9.3	Subalpine range	M, N, E	Compton and Brundage (1971)
9.7	10.5	3.8	Summer range	M, E, MN	Dwyer (1961)
10.2	7.4	5.0	Year-long prairie	M, N, E, MN	Kropp et al. (1973)
10.6	8.2	5.2	Mountain range	M, E, MN	Gonzalez (1964)
11.0	8.0	5.0	Heavy stocking rate	M, N, E, MN	Peterson and Woolfolk (1955)

[a] M= early morning, N = mid-day, E = evening, MN = midnight.

Environmental Factors That Modify the Daily Routine

Climate

High temperatures. Researchers working with cattle in warm climates have found that air temperature can appreciably modify their daily routine. Temperature exerted considerable influence on the cows with calves studied by Dwyer (1961). They grazed fewer hours, spent more time cooling in the water ponds, and less time lying on days when the temperature exceeded 85° F. For every increase of 1° F in average daily temperature there was a decrease of 0.13 hours spent grazing during the day. When the temperature approached or exceeded 90° F, there was a noticeable increase in the respiration rate of the cows. Dwyer suggested that these changes in behavior partially explain the decrease in pounds gained by these cattle during July and August, due to a decrease in both feed intake and the amount of net energy retained from the feed. High temperatures also cause cattle to commence grazing earlier in the morning and to extend the evening grazing period further into the night (Hein, 1953).

Moderate temperatures. One of the major conclusions drawn by Shepperd, Blaser, and Kincaid (1957) was that maximum and minimum daily temperature variations did not influence cattle behavior. Gonzalez (1964) also felt that air temperature had no influence on the total daily grazing time or on the distance traveled each day. Grazing during the middle part of the day was found by Sneva (1970) to be variable and not related to the mean air temperature of the day. Perhaps one may then assume that moderate temperatures have little, if any, effect on the daily routine of range cattle.

Low temperatures. Although Box, Brown, and Liles (1965) felt that air temperature had little effect on the activities of cattle during the winter, Smoliak and Peters (1955) found that the mean daily temperature was the most important factor in determining the number of cattle foraging on any given winter day (as opposed to those seeking shelter). The difference here may merely be one of extremes. It is evident that extremely low temperatures do cause distinct physiological responses in dairy cows. McDonald and Bell (1958) measured various physiological responses of lactating dairy cows at air temperatures ranging from 45° F to 2° F. The rectal temperature of the cows rose from 100.32° F at an air temperature of 45° F to 101.15° F at an air temperature of 10° F. The number of heart beats per minute rose from 66 at 45° F to 70 at 2° F. The number of respirations per minute dropped from 20 at 45° F to 14 at 2° F. Similar results were obtained when Olsen (1969) stanchioned eight non-lactating dairy cows in a temperature controlled room and dropped the temperature, at approximate weekly intervals, from $+23^{\circ}$ C, to $+1^{\circ}$ C, to -21° C, to -24° C, and finally to -29° C. The cows' blood pressure rose to a maximum of 25 millimeters of mercury after 6 days. Their heart beat increased to a maximum of 30 per minute at 9 days. Their respiratory rate decreased gradually to a minimum of 7 per minute. Webster (1970) concluded that cold winter weather has a significant, but not drastic, effect on unsheltered pregnant beef cows receiving an adequate diet. This effect would not be great enough to prevent beef production in areas which normally undergo severe winter weather. He also stated that the critical temperature (the temperature below which an animal must increase its metabolic heat output in order to maintain a constant body temperature) for a mature, pregnant beef cow is approximately - 11° C in November, - 16° C in December, - 18° C in January, - 20° C in February, and - 23° C in March under "still air" conditions. Physiological changes and stresses such as these would obviously have an effect on the energy expenditure and perhaps on the behavior of cattle exposed to severe winter weather.

Humidity. Humidity *per se* apparently does not ffect cattle activities to a great extent. Few researchers have reported any significant results directly linked to humidity fluctuations. However, evidence indicates that humidity does modify the effects of temperature and wind on cattle grazing activities (Dwyer, 1961). Ehrenreich and Bjugstad (1966) developed a temperature-humidity index:

$$THI = 0.4\,(T_d + T_w) + 15$$

THI = temperature-humidity index

T_d = dry bulb temperature

T_w = wet bulb temperature

which correlated with the total grazing times of steers on hot days. As THI values rose above 73, cattle grazing time dropped sharply. The steers responded quickly to slight rises in THI values above the 60-70 range by seeking shade.

Wind. The effects of wind are also more notable when coupled with extremes in other climatic conditions, especially high and low temperatures or precipitation. Dwyer (1961) noted that the cattle he observed spent 73.1 percent of the time with their sides toward the wind while standing. He felt that this was done to increase the circulation of air around the body, thus increasing heat removal. During rainstorms they grazed with their heads downwind, apparently to reduce heat loss. The cattle observed by Culley (1938) spent considerably more time in washes on windy days. They were restless and traveled farther in stormy and windy weather. Other researchers (Box, Brown, and Liles, 1965; Rutter, 1968) report that high wind velocities cause cattle to cease grazing and seek shelter.

Webster (1971) developed a "Moocow" heat loss simulator which measured the metabolic heat loss of cattle exposed to cold outdoor environments. He concluded that windspeed, air temperature, and surface radiation exchange all affect heat loss greatly. He calculated that the critical temperature of a pregnant beef cow increases from -17° C at a windspeed of 1 mile per hour, to -11° C at a windspeed of 10 miles per hour, and to -4° C at a windspeed of 27 miles per hour under conditions of constant air temperature and radiation exchange. Application of Young's formula for estimating cold stress in beef cattle results in practically identical critical temperature values for an average beef cow.

While developing an index of winter weather severity for deer, Verme (1968) stated that air temperature and windspeed are the most important factors which influence the effects of winter weather on animals. Decreasing air temperature combined with increasing windspeed produce the most severe conditions which animals must tolerate.

Precipitation. Some of the effects which rain and snow storms have on the daily routine of cattle were previously mentioned in conjunction with the effects of temperature and wind. Several facts are evident. Mild rain showers have little effect on grazing activities. Cattle merely tend to graze more slowly until the shower passes. Heavy rain coupled with wind causes them to huddle facing downwind or seek shelter. They prefer to stand, rather than lie on the wet ground both during and for a short period following the rain (Dwyer, 1961; Tayler, 1953). It has also been noted that cattle often graze more intensively for several hours preceding and immediately following a storm (Rutter, 1968).

Light. Results concerning the influence of light on grazing activities are varied. It was previously mentioned that many studies indicate the "cow-day" of daytime activities normally begins a few minutes before dawn and ends shortly after dark. After observing cattle during the daylight hours at monthly intervals for one year, Reppert (1960) stated that grazing time is largely a function of day length. Hein (1935) reported that nocturnal grazing does occur, but only under bright moonlight. The cattle observed by Pearson-Hughes and Reid (1951) did not graze at night in the summer, but did graze to a small extent at night in the autumn. Up to 10 percent of the yearling steers in a feedlot were found feeding at any time of the night by Roubicek and Hubbert (1961). They also stated that cattle behavior studies must include observations of nocturnal activities in order to obtain valid results. Some researchers have found that night grazing may comprise as much as 18 percent (Dwyer, 1961), 20 percent (Smith, 1959), or even 40 percent (Johnstone-Wallace and Kennedy, 1944) of the total grazing time. The major portion of nocturnal grazing apparently takes place around midnight.

An interesting study by Compton and Brundage (1971) demonstrated that cattle behavior is not necessarily governed closely by light or day length. These researchers observed the activities of cattle on a subalpine range in Alaska. Day length decreased from 17.8 hours at the beginning of the study, to 10.2 hours at the end. The cattle followed a systematic daily routine. In fact, it was practically identical to the routines described earlier in this review, but independent of the sunrise and sunset. The amount of time spent in major activities was also similar to that of cattle in areas with considerably shorter day lengths (see Table 1).

Season. Changes in the daily routine frequently occur in conjunction with seasonal changes. For example, as winter approaches, mid-day grazing is intensified (Tayler, 1953), idle time may decrease (O'Donnell and Walton, 1969), the ratio of ruminating time to grazing time may increase (Herbel and Nelson, 1966), and defecation rates tend to decrease (Wagnon, 1963). Seasonal change was the largest source of variation in cattle activities in a year-long study by Kropp et al. (1973). However, changes in cattle activities can not be directly attributed to the change in seasons. They should be considered in relation to the climatic and vegetational changes (temperature, precipitation, phenology of the vegetation, and day length) which more directly influence the animals' activities.

Topographical influences on grazing activities

Topography may influence the daily routine to some extent. Gonzalez (1964) found that the percent slope and the exposure where cattle grazed were important factors in determining the total time spent grazing per day. His cattle spent more time grazing on the more gentle slopes and avoided the steepest areas altogether. The influence of exposure may be due to its effect on vegetative growth patterns and plant species distribution. Topography is also important in the sense that washes and ridges provide protection from the wind (Culley, 1938). Cattle will apparently continue to graze during storms if they are able to do so in the protection of a topographical feature.

Management regimes

Grazing intensity. Increased stocking rates resulted in more vigorous foraging and extended grazing times by Hereford cows and calves on short grass range (Peterson and Woolfolk, 1955). Cattle observed by Grelen and Thomas (1957) spent 10 hours grazing per day (56 percent of the time) and 4 hours resting under heavy grazing intensities. The grazing time was only 7.5 hours (22 percent of the time) under light grazing conditions, while the resting time remained at 4 hours.

Grazing systems. A comparison of continuous versus rotational grazing systems and of pastures with a mixture of various plant species versus monospecific pastures by Shepperd, Blaser, and Kincaid (1957) resulted in the conclusion that the time spent grazing each day was the same in all pastures under both grazing schemes. The time spent grazing differed from day to day, but the overall routines were not significantly different. Tayler (1953) obtained similar results. Different grazing systems evidently affect cattle behavior only as they may dictate the season of use or the availability of palatable forage.

Supplemental feeding. Cattle which received a daily winter supplement of cottonseed cake were found to be easier to handle, spent more time ruminating, and traveled less distance daily than cows which received no supplement (Box, Brown, and Liles, 1965). Wagnon (1963) compared the behavior of beef cows receiving supplements to non-supplemented cows on a California range. The non-supplemented cows spent 56 percent of the time grazing. The supplemented cows spent only 44 percent of the time grazing and twice as much time resting as the other group.

Availability of water and salt. Considering that cattle normally drink from 1 to 8 times daily (Hancock, 1953) and consume salt approximately once every 34 hours (Dwyer, 1961), the availability of water and salt to cattle influences their activities significantly. Cattle tend to remain concentrated near an ample water supply. An increase in the number of watering places throughout an area results in a more uniform distribution of cattle (Gonzalez, 1964). It also means that they have less distance to travel between water and forage. Sneva (1970) noted that 75 percent of the traveling time and 20 percent of the grazing time occurred immediately preceding and following the time spent watering.

Although cattle may have to travel a considerable distance to water in some areas, it should be noted that the energy expended in walking is a small amount compared to that exerted in other behavioral and metabolic activities (Blaxter, 1962). This was demonstrated in a practical manner by Gonzalez and Butcher (1962). They exercised Hereford steers 4.2 miles per day at 2 miles per hour for 30 consecutive days. No significant differences were found between the weights of the exercised steers and a control group confined in a small pen and fed at the same rate.

Shelter. Shelter, in the form of shade from the sun during hot weather, apparently affects both cattle behavior and production. Cattle with ample available shade graze less at night, spend less time standing and lying idle during the day, and gain weight more rapidly than cattle deprived of shade (McDaniel and Roark, 1956).

Shelter from cold weather stress may not be as influential on cattle activities. Young, Dietz, and Berg (1972) reported that, although shelters were beneficial for cows in reduced body condition during periods of severely cold weather, when considered over the whole winter cows with stalls and bedding had little advantage. In fact, it was not sufficient to cover the cost of the shelters. However, they did recommend that the feed ration be increased during periods of cold stress to provide the animals with additional energy to maintain their body temperature. Robinson (1960) reported similar results with penned White-tailed deer. The amount of natural cover present had no effect on weight losses or behavior during the winter months. He attributed this to the fact that all the deer chose bedding sites with approximately identical micro-climates, regardless of the total amount of cover available in each pen.

Forage quality and quantity

Grazing time is often correlated to the palatibility of herbage (Shepperd, Blaser, and Kincaid, 1957), the amount of forage available (Hein, 1935), and the phenology of the plants (Compton and Brundage, 1971). Grazing time increases with lowered palatability, less available forage, and/or maturation of the foliage. The total amount of feed consumed may also decrease as the amount available decreases (Johnstone-Wallace and Kennedy, 1944). The same factors tend to decrease the daily defecation rate (Wagnon, 1963).

Harris, Frischknecht, and Sudweeks (1968) found that the patterns of use exhibited by cows, calves, and yearlings grazing crested wheatgrass at a 60 to 70 percent level of utilization changed as the grass matured. The cattle showed an increasing preference for seedheads, the grass in swales, and the grass growing immediately around and under rabbitbrush plants. Use in these areas was 15 percent heavier than on the ridges and flats where rabbitbrush plants were absent. Use patterns are also influenced markedly by plant community or vegetative type distinctions (Gonzalez, 1964). O'Donnell and Walton (1969) used the following formula to determine cattle's preference for various vegetative types within a pasture:

$$\frac{\text{Percent of Grazing time in type}}{\text{Area of type}} = \text{Preference for the type}$$

The ratio of ruminating time to grazing time is evidently related to the TDN (total digestible nutrients) content and digestibility of the forage. Loffgreen, Meyer, and Hull (1957) concluded that the ratio decreased as the TDN content of the forage increased. It also decreased as the digestibility of the forage being selected increased. They also noted that the cattle ruminated more on the fifth day after being placed in a pasture than they did on the second day. A study by Herbel and Nelson (1966) in Southern New Mexico showed the same relationship between the ratio of ruminating time to grazing time and the TDN content of the forage. The value also changed with the season, due to the maturation of the forage. It rose from 0.64 in the spring, to 0.66 in the summer, to 0.80 in the fall, and to 0.81 in the winter for Hereford cattle.

Animal-Related Factors Modifying Grazing Behavior

Breeds

The adaptability of various breeds of cattle to environmental variations is perhaps self-evident. In general, breeds adapt more readily to conditions which are most similar to those where the breed originally evolved. Two studies are cited as typical examples of differences between breeds. Smoliak and Peters (1955) compared the foraging performance of Hereford, Shorthorn, Angus, 1/2 Bison, and 1/4 Bison Cattalo breeds on a Canadian winter range. The number of cattle foraging of each breed (as opposed to those seeking shelter) was counted each day and correlated to the mean air temperature, wind-speed, and amount of supplements the cattle had received. At temperatures below - 7^{o} C, the 1/2 Bison Cattalo spent the most time foraging, even though supplements and shelter were readily available. They were followed by the 1/4 Bison Cattalo, Shorthorn, Angus, and Herefords. The Shorthorns lost the most weight during the period.

Moran (1970) compared the Brahman and Hereford breeds in a temperate environment. He found no major breed differences. The ratio of ruminating time to grazing time of the Brahmans was slightly lower while the forage was green, but it rose to the same level as that of the Herefords later in the season. Breed differences are apparently one of the smallest sources of variation in grazing activities (Kropp et al., 1973).

Social facilitation

Beef cattle grazing together in a herd generally function as a single unit. For example, they spend about the same amount of time grazing, travel to water in a group, and bed down at approximately the same time (Hein, 1935). Leyhausen (1971) states that the "majority rule" usually determines the behavior of a group of cattle. The group tends to graze as a unit, rather than follow a specific leader. When the group is frightened, the first animal to move becomes the leader until the group is out of danger. While O'Donnell and Walton (1969) also observed that cattle in a herd act in unison, they felt that two or three older animals were the herd leaders. The leaders determined the activity patterns for the entire group. Aside from the issue of which animal may or may not be the leader, it is thus evident that "group pressure" may influence, or modify, the daily routine of individual animals towards the average of the group as a whole.

Research Methodology

General techniques

Researchers have been able to observe cattle closely from a pickup truck (Dwyer, 1961), on horseback (Gonzalez, 1964), or afoot (Box, Brown, and Liles, 1965), depending upon the terrain and the amount of caution exercised to avoid disturbing the animals. The foregoing researchers felt that more accurate results are obtained by observing an individual cow, rather than attempting to monitor the activities of the entire herd. Binoculars or a low-power spotting scope have proven extremely useful in numerous studies. The use of a flash-light is necessary to observe nocturnal activities accurately. The cautious use of a light evidently does not disturb the cattle (Dwyer, 1961). Some researchers have painted large numerals on the animals' sides to facilitate the identification of individual animals. Nelson and Furr (1966) brushed glass beads onto the wet paint to aid nocturnal observations. The important points seem to be the exercise of caution to avoid dis-burbing the animals and of extreme patience to keep an individual animal under close scrutiny for long periods of time.

Interval of observations

Continuous versus intermittent observations were studied by Hull, Lofgreen, and Meyer (1960). They concluded that observations conducted every 30 minutes were adequate to determine the time spent grazing, ruminating, and idling. Minor behavior patterns required more frequent observations. Nelson and Furr (1966) concluded that observation intervals must be less than 15 minutes. Pearson-Hughes and Reid (1951) felt that observations every four minutes gave sufficiently precise results for all activities. It may be noted that an observer must remain constantly near the cattle in order to observe them every fourth minute. Perhaps he may as well conduct continuous observations, which would require approximately the same amount of effort. There is little doubt as to the validity of continuous observations; provided, of course, that the observer is conscientious and is able to conduct observations for long periods of time without becoming too fatigued.

Sample numbers

In order to obtain reliable estimates of herd behavior, Hull, Lofgreen and Meyer (1960) recommend that at least four animals per treatment be observed individually. Gary, Sherritt, and Hale (1970) stated that six periods of 24-hour observations were insufficient to quantify loafing, lying, and eating activities. The accurate estimation of nursing times for cows with young calves required the observing of more than nine different pairs. Sample numbers must evidently be quite high in order to accomodate the variation that exists between the daily activity patterns of individual cattle.

Automated techniques

Some work has been done toward developing instruments which would automatically record cattle grazing activities. Rutter (1968) devised a system which recorded livestock activities on 8-mm photographic film at the rate of one picture per minute. The windspeed, air temperature, and precipitation were also recorded with instruments. Duckworth and Shirlaw (1955) developed an apparatus which recorded the jaw movements of cattle housed indoors. They later compared this data with data collected by continuous visual observations of cattle in pastures (Duckworth and Shirlaw, 1958). They concluded that the recorded jaw movements were more valuable than visual observations in studying the patterns and duration of rumination periods. Such methods would certainly eliminate the possibility of errors due to observer fatigue, but they would be difficult to use on free-ranging cattle in rough or brushy country. Perhaps their potential should best be considered in connection with cattle housed indoors or in relatively small, open pastures.

Indirect methods

Indirect methods of determining grazing use may not appear to be especially applicable to studies of grazing behavior. However, they may serve as points of reference upon which to evaluate such studies. For example, by sampling the number of fecal deposits on an area, Julander (1955) determined that cattle grazing on crested wheatgrass

(Agropyron cristatum) in the spring defecate 11.5 times per day. This figure could be compared to that obtained in a study of grazing activities on a similar area during another season of the year. Any differences may be evaluated in terms of what environmental conditions or activity patterns may have resulted in the variation.

The Interrelationship of Animal Behavior to Bioenergetics and Production

It has been shown that cattle activities are often modified by variations in environmental conditions. Such behavioral changes can be attributed to efforts by the animal to avoid stresses which would result in increased energy expenditure. The conservation of energy is especially important as it relates to animal production, whether it be in the form of growth, milk, or reproduction. Blaxter (1962) indicates that the energy metabolism and behavior of beef cattle are affected by such factors as insulation of the skin and coat, diet, body weight, windspeed, radiation exchanges, and wetness of the animal's coat. He stresses that constantly changing weather conditions outdoors make it extremely difficult to measure or estimate metabolic energy expenditures by animals.

The rates of energy expenditure by cattle while eating, ruminating, standing and walking indoors have been determined in laboratory experiments (Christopherson and Young, 1972). Animals increase their energy expenditure while engaged in such activities. They are part of an animal's normal process of obtaining nutrients and can be a major part of the maintenance energy requirements of an animal, especially the range animal. Knowledge of the energy costs of various activities and the time spent in each activity can be used to predict the approximate daily expenditure of energy for those activities. Their relationship to net animal production and environmental conditions can then be determined for consideration in forming management and research policies.

Body temperature maintenance is a critical factor in the energy budget of range cattle. The anatomical adaptations and physiological mechanisms which enable mammals to maintain a relatively constant body temperature under fluctuating environmental conditions are discussed by Irving (1964). Such factors as changes in the rate of metabolic heat production, the insulative properties of the skin and pelage, heat loss through evaporation, the amount of radiation received from the sun, the ability to vary skin temperature, sensory temperature detection mechanisms, body size, and the size and shape of extremities all play an important role in the energy budget of mammals. He also states that behavior is constantly altered in response to changing environmental conditions. The researcher must be aware of these environmental influences and animal responses in order to evaluate the activities of range cattle in a precise manner.

DESCRIPTION OF THE STUDY AREA

The study was conducted on property owned by the United States Bureau of Land Management located approximately 15 miles southwest of Snowville, Utah. The site comprises approximately 5,000 acres, of which 3,200 acres were plowed and seeded with crested wheatgrass (*Agropyron cristatum*) in 1965 (Figure 1). The stand of crested wheatgrass is uniform and generally forms a vigorous, closed community. Several small patches of halogeton (*Halogeton glomeratus*) and summer cypress (*Kochia americana*) are present on the less favorable sites.

A swale, ranging in depth from approximately 2 to 6 feet, tranverses the seeded areas from north to south. Considerable invasion by big sagebrush (*Artemisia tridentata*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) and Great Basin wildrye (*Elymus cinereus*) has occurred in the swale.

The remainder of the area remains in native salt desert shrub vegetation. The dominant plant species in this type are big sagebrush, shadscale (*Atriplex confertifolia*), Douglas rabbitbrush, bottlebrush squirreltail (*Sitanion hystrix*) and Indian ricegrass (*Oryzopsis hymenoides*) (Stoddart and Smith, 1955).

The elevation is approximately 4,350 feet above sea level. With the exception of the swale and a ridge which rises sharply at the extreme eastern end of the site, the topography is relatively level.

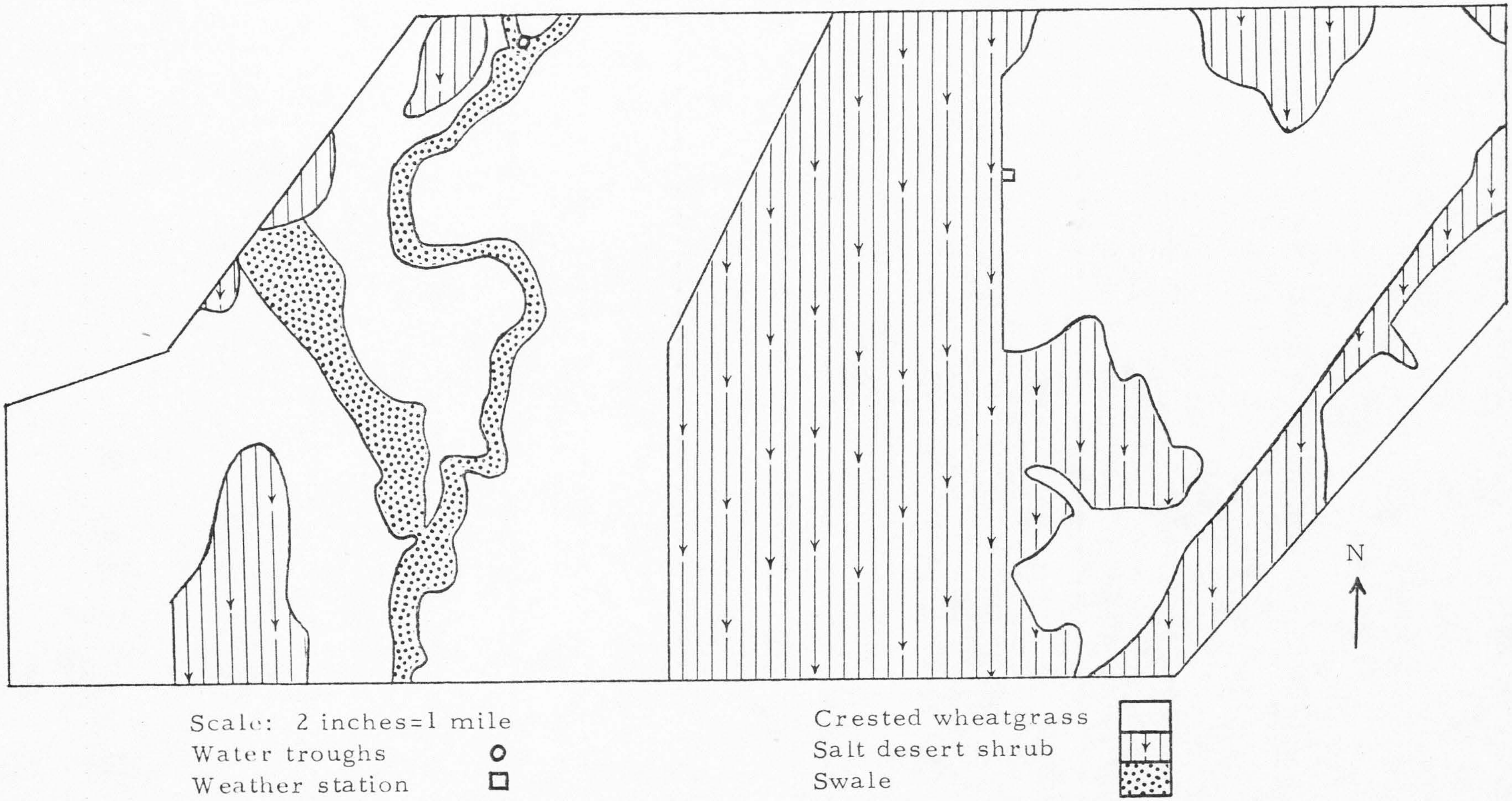

Figure 1. A map of the study area southwest of Snowville, Utah.

Fresh water is available to the cattle in troughs located near the northwest corner of the area (see Figure 1).

An IBP (International Biological Program) Desert Biome study site and meteorological station are located on the eastern portion of the area.

Five hundred head of cooperator-owned beef cattle graze the area from mid-November to the latter part of January each winter. In 1972, the schedule was altered to allow additional grazing during the month of April. The majority of the cattle are pregnant Hereford cows. Some replacement heifers and Aberdeen-Angus cows are also present in the herd. They receive no supplements or salt during their stay in this area.

METHODS AND PROCEDURES

This study was undertaken in conjunction with a two-year IBP Desert Biome project designed to determine the grazing use by cattle on the IBP study site and to develop a budget of daily energy expenditure by the cattle. Therefore, the data was collected in a manner which would accomplish the purposes of both studies simultaneously. Cattle activities were observed during three grazing periods. The first period commenced on Novermber 15, 1971, and terminated January 20, 1972. The second began April 1, 1972, and ended April 30, 1972. The third period lasted from November 24, 1972, to January 29, 1973. They will be referred to as the 1971-72 period, the April 1972 period, and the 1972-73 period, respectively.

The weights of 23 individual cows were obtained before and after the 1971-72 grazing period to determine weight changes during the period. These weights are listed in the Appendix (refer to Table 9). Due to a change in livestock management procedures, it was impossible to weigh the cattle before or after the other two grazing periods.

An individual cow was observed continuously during the cow-day[1] at irregular intervals during the 1971-72 period, for a total of 15 observations. Nocturnal herd activities were observed three times, on the

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[1] A cow-day was defined as commencing when the cow arose to begin the daytime activities and ending when she bedded down for the night.

14th, 21st, and 28th nights of the study period. During the April 1972 period, ten cows were observed individually during the daylight hours. Seven of these observations were extended to 24 hours in an attempt to more accurately quantify nocturnal activities. Due to the wariness of the cows with young calves, the observer could not remain close to the cattle at night during this period. Therefore, it was only possible to record the time spent nursing and grazing during the nocturnal hours. During the 1972-73 period, an individual cow was observed continuously for 24 hours every fourth day, for a total of 15 observations. Each observation began when the cow first arose in the morning and ended at the same time the following morning.

The observation techniques were identical during all three grazing periods. The cow which was bedded down nearest to the IBP weather station was chosen for observation. Individual markings, such as coloration patterns, brands, earmarks, and horn characteristics were noted. This ensured that the same cow was observed throughout the observation period, and also that the same cow was not observed twice during the study period.

The observations were made from the cab of a pickup truck. By traveling slowly and avoiding sudden movements or noises, the observer was able to remain within 50 yards of the cow the majority of the time. A pair of 7X35 binoculars and a 10X-60X variable spotting scope were used when the cow entered shrubs too tall to permit travel by vehicle or crossed the IBP study site. A flashlight was used for night-time observations. The light apparently did not disturb the cows unless it was shined directly into their eyes from short distances.

A continuous log of the animal's activities was kept during each observation period (Figure 2). Every change in activity was recorded to the nearest minute. The activities recorded were: grazing, standing ruminating, lying ruminating, standing idle, lying idle, traveling, and drinking. Each defecation and urination was recorded as it occurred.

The amount of time spent in each vegetative type was also recorded to the nearest minute. Salt desert shrub, crested wheatgrass, the swale, and the sacrifice area around the waterhole were considered as distinct vegetative types.

An aerial photograph having a scale of 4 inches to 1 mile was used to determine the route travelled by each cow. The route was traced on an acetate sheet super-imposed over the photograph. The tracing was measured in inches and converted to the number of miles travelled during the observation period.

Air temperature, windspeed, relative humidity, and net solar radiation recordings for the 1971-72 and 1972-73 winter study periods were obtained from the IBP Desert Biome weather station located in the study area (see Figure 1). Barometric pressure was recorded on a baroscribe (continuously recording barometer) placed in the weather station. Snow depth was measured during each observation period. Notes on general weather conditions and storms were kept on the daily log sheet. This information was summarized and analyzed to provide

Date: January 8, 1973

Activity	Time	Type	Defs.	Urins.	Notes
SI	7:25	AGCR	1	1	Snow Depth 6", crust
Grz	7:26				Overcast, light wind
SI	8:20				Broadside to sun
Grz	8:28				
SI	10:12				Broadside to sun,
SR	10:19				head downwind
Grz	10:24		1		
	11:17	ARTR			
	11:46	AGCR			

Figure 2. A partial log sheet of an individual cow's activities during one 24-hour observation period.

a reasonably accurate measure of the climatic conditions and changes during each observation period.

RESULTS AND DISCUSSION

The Normal Daily Routine of Cattle Activities in the Winter

The cow-day

It soon became apparent that a normal daily routine of cattle activities did exist. The routine varied slightly from day to day, but the general pattern remained essentially the same throughout the 1971-72 and 1972-73 winter grazing periods. This pattern is displayed graphically in Figure 3. It is largely based on average values for the two grazing periods. The variations and extremes which occurred in the routine will be discussed in later sections.

The cow-day began about 7:15 a.m. (one hour before sunrise) each morning. The cows arose from their beds and stretched, extending their legs and neck and curling their tails over their backs. They then stood idle for 5 to 10 minutes. During this time, they defecated and then urinated. Intensive grazing took place from this time until sunrise. As soon as the sun's rays began to shine directly on the cattle, they turned broadside to the sun and stood idle for approximately 15 minutes. During this time they stood quietly with their eyes closed and their ears laid back against their head. This idle period was followed by another intense grazing period.

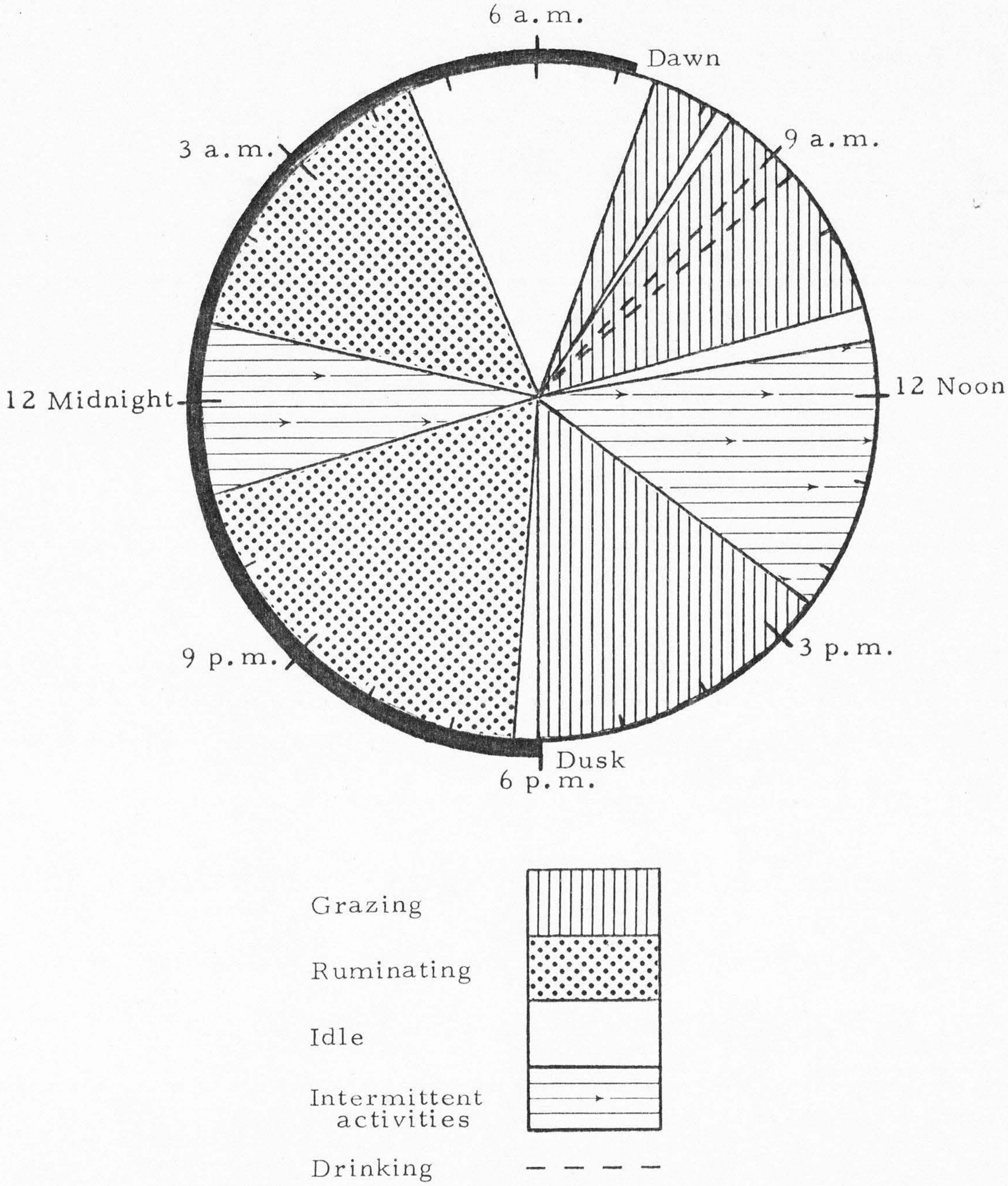


Figure 3. The normal daily routine of cattle activities on winter range as observed during the 1971-72 and 1972-73 winter grazing periods.

On days when the cattle drank, they grazed slowly toward water during the morning grazing period. At approximately 9:00 a.m. they began to walk rapidly toward the water troughs, sometimes stopping to take several bites before continuing. The time spent walking to water depended on the distance it was necessary to travel. It varied from 5 to 40 minutes. The cattle normally travelled single file along a road or established trail directly toward the troughs. Each cow spent from 3 to 5 minutes drinking. Some time was spent jostling and pushing for a place at the trough when many cattle arrived to drink at the same time. After drinking, they stood idle for perhaps 10 minutes, then returned to graze. Grazing was usually resumed within 200 yards of the water troughs, but 35.7 percent of the observed cattle which drank returned to the same general area where they had spent the morning before they resumed grazing. They then grazed intensively until approximately 11:00 a.m.

On days when the cattle did not drink, they continued to graze steadily from the idle period after sunrise until 11:00 a.m. Groups of 10 to 30 cows grazed together as separate, but loosely-knit units during this time. Each group grazed in what appeared to be a random fashion over the area, with no apparent objective in mind.

The cattle usually stood broadside to the sun for 20 minutes around 11:00 a.m. They generally stood quietly during this time, but sometimes ruminated briefly or groomed themselves with their tongues.

The time from 11:30 a.m. to 2:30 p.m. was spent in intermittent activities. Some two hours of this period consisted of desultory grazing. Grazing was often interrupted by short (10 to 45 minute) periods of standing idle. The cattle often stood rubbing for several minutes on the steel posts which mark the IBP study site boundary or on tall sagebrush plants. An occasional pushing contest broke out among the younger heifers. The cattle sometimes ruminated for short periods, but it was not the general rule. Only 3 of the 30 cows observed laid down during this intermittent period.

After a short idle period about 2:30 p.m., the cattle resumed grazing intensively until 6:00 p.m. They then chose a bedding site. Sometimes they grazed directly to a site, other times they wandered about for several minutes, apparently seeking an appropriate spot or the company of several other cows. They usually bedded down in groups of from 5 to 30 cows, and never completely alone. Certain areas, such as the swales or certain groups of shrubs, were evidently preferred as bedding sites. The cattle used several of these same areas regularly during all of the grazing periods.

Upon reaching a bedding site, from 15 to 60 minutes was spent standing idle or ruminating, then the cows lay down for the night. This usually occurred about 6:30 p.m. (or shortly after dark) and was considered the end of the cow-day.

The normal daily routine exhibited by these cattle is similar to that described by other researchers (Moorfield and Hopkins, 1951;

Smith, 1959; Kropp, 1973), as outlined previously in this paper. The morning and evening periods of intense grazing are evidently characteristic of most range cattle. The mid-day period of desultory grazing mingled with short idle periods is also a generally characteristic part of the daily routine (O'Donnell and Walton, 1969). The initiation and termination of the cow-day in coincidence with dawn and dusk is also agreeable with other studies (Dwyer, 1961). One major difference noted is that only 10 percent of the cattle in the present study lay down at any time during the cow-day. This was most likely due to the cold, wet snow which covered the ground during most of the study period. Other researchers (Dwyer, 1961; Tayler, 1953) have reported that cattle preferred to stand rather than lie on the wet ground immediately following a rainstorm. They evidently react to snow in a similar manner.

Nocturnal activities

During the 1972-73 period, when all nocturnal activities were monitored, fairly steady rumination occupied the time between 6:30 p.m. and 11:00 p.m., with very few minutes spent idle. During the first two weeks that the cattle were on the seeding, they arose at 11:00 p.m. to graze for approximately 1.5 hours. After two weeks, the period from 11:00 p.m. to 1:00 a.m. consisted of intermittent activities. The cattle lay idle with their eyes closed, occasionally ruminated, or arose to stretch, defecate, and stand idle for 10 to 45 minutes. Due to the fact that the cessation of nocturnal grazing occurred with the accumulation of a snow cover, it is speculated that the presence of the snow cover contributed to this change in behavior.

By 1:00 a.m., they had lain down and resumed steady rumination. This lasted until approximately 4:30 a.m., at which time the cattle stopped ruminating but remained idle, apparently asleep, until the cow-day began again at 7:15 a.m.

It should be mentioned that it was impractical to attempt continuous observations with a flashlight throughout the night. The observer remained close to the cattle and shined the light on them, just long enough to observe their current activity, every 10-15 minutes. Some urinations and defecations may have been missed, but it is felt that the observations of other nocturnal activities are reasonably complete and accurate.

Three nocturnal observations were conducted during the 1971-72 grazing period. The cattle grazed for approximately 2.0 hours the first night. They did not graze during the other two nights, indicating a similar pattern of nocturnal activities for both years' grazing periods.

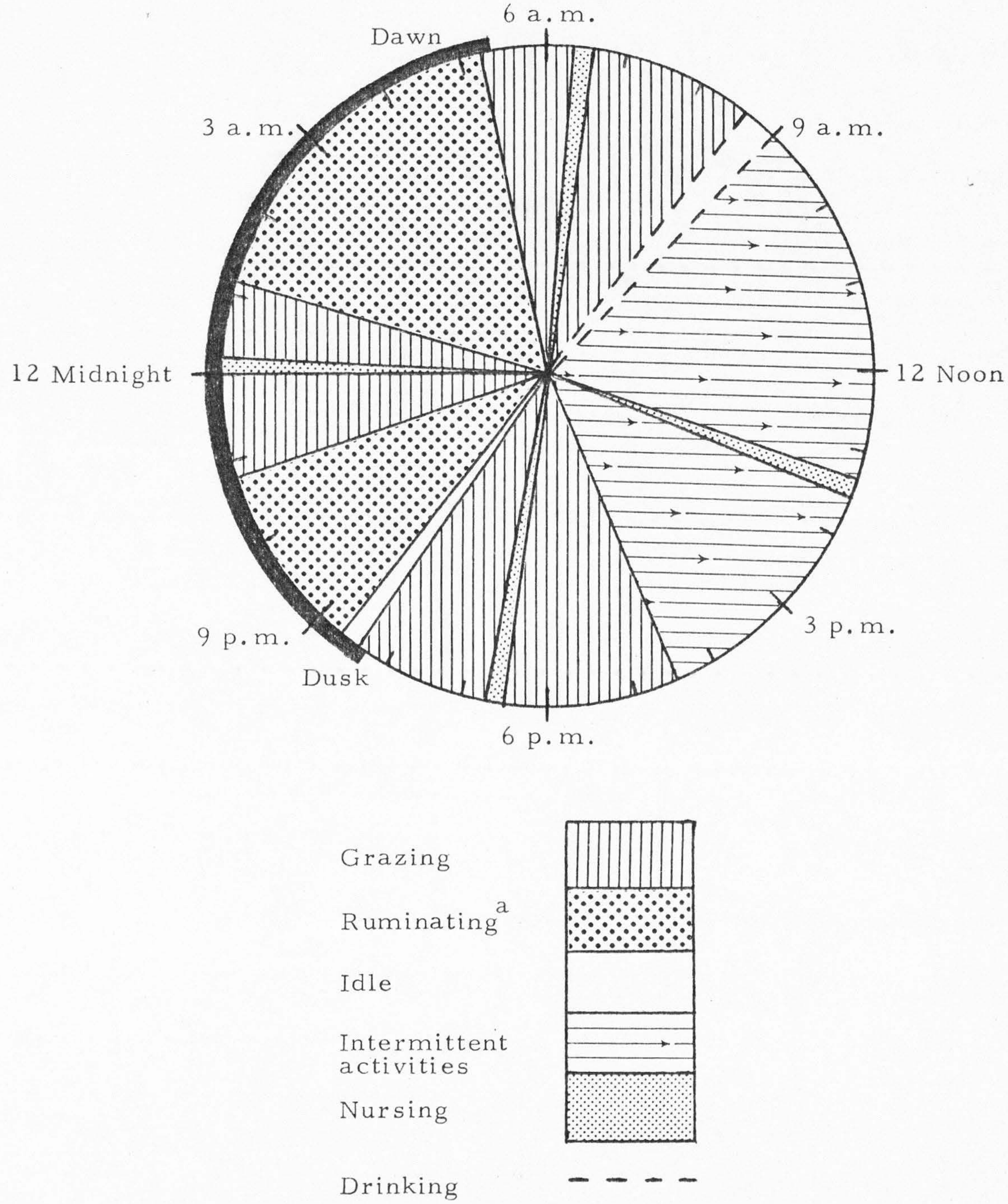
The lack of nocturnal grazing by these cattle differs from the findings of some researchers (Johnstone-Wallace and Kennedy, 1944; Smith, 1959). However, those researchers who observed cattle which grazed extensively at night did so under conditions of moderate temperatures and a lack of snow cover. Night grazing was also usually accompanied by relatively hot temperatures during the day. Cattle in these two studies were evidently attempting to avoid energy loss and stress induced by heat. Our cattle were at the other extreme. They apparently attempted to conserve heat energy by restricting grazing to the daylight hours when ambient temperatures were somewhat less severe.

The Normal Daily Routine of Cattle Activities in the Spring

The cow-day

The daily routine in the spring was markedly different from that during the winter. However, it was also essentially unchanged from day to day. It is displayed graphically in Figure 4.

The cow-day began at approximately 5:15 a.m. The cattle arose from their beds, stretched, and immediately defecated and urinated. After standing idle for perhaps 5 minutes, they began to graze intensively. Grazing was interrupted at 6:20 a.m., when the calves arose to nurse. Each cow stood quietly, often ruminating or grooming the calf with her tongue, while nursing. The nursing period generally comprised about 10 minutes, after which the cattle returned to intensive grazing. At an average time of 8:30 a.m., they ceased grazing and started walking towards the water. After traveling for approximately 20 minutes, they arrived at the troughs, drank for 5 minutes, and then stood idle for 5 to 15 minutes. The period of time from 9:00 a.m. to 4:30 p.m. was one of intermittent activities. The cows alternately stood idle, stood ruminating, usually lay idle or ruminating for 1 to 2 hours,



[a]Estimated time spent in nocturnal rumination.

Figure 4. The normal daily routine of cattle activities in the spring as observed during the April 1972 grazing period.

or grazed in a desultory fashion. They nursed their calves once at approximately 1:15 p.m. Some time (10 to 20 minutes) was spent during this period each day rubbing on shrubs, the steel posts marking the IBP study site boundary, the fence, or the water troughs. This apparently aided the shedding of their shaggy winter coats. This activity was recorded as time spent standing idle.

Intensive grazing occupied the time between 4:30 p.m. and 8:20 p.m., with 10 minutes of nursing occurring around 6:30 p.m. After standing idle or ruminating for some 10 minutes, they bedded down at 8:30 p.m.

Nocturnal activities

The presence of young calves in the herd rendered it impossible to obtain complete and accurate observations of all nocturnal activities. If the observer approached close enough to distinguish between rumination and idleness, the cows quickly arose and moved out of the range of the flashlight. A brighter light only excited them to a greater degree. This wariness was most likely due in part to the abundance of coyotes in the area. The cows paid strict attention to their howling and yapping throughout the night. Therefore, grazing and nursing were the only activities recorded during the "cow-night."

The cattle lay quietly, apparently idle or ruminating, the majority of the night. The major difference detected between the spring and winter nocturnal hours was in grazing activity. The cattle arose to graze every night of the spring grazing period. They arose to graze at the average time of 10:50 p.m. and ceased grazing by 1:10 a.m. This amounted to 1.61 hours of grazing each night. The calves usually nursed once during the night grazing period and several minutes were spent standing idle or ruminating.

This routine is very similar to that described by researchers in more temperate climates (Dwyer, 1961; Kropp et al., 1973). The variations in daily activities exhibited by these cattle between the winter and spring grazing periods not only supports the theory that cattle modify their behavior in accordance with changing climatic conditions, but it also demonstrates that these cattle behaved basically the same as other cattle would under similar climatic conditions.

Individual Cattle Activities During an Average 24-hour Period

Grazing

Grazing occupied the major portion of the cattle's time in both winter and spring. Approximately 39 percent (9.33 hours) of the average winter's day was spent grazing (Table 2). Some 95.6 percent of the grazing took place during daylight hours in winter, with the remainder occurring around midnight during the first two weeks of the study periods. In contrast, 50 percent (12.02 hours) of the average day was spent grazing during spring (see Table 2). Approximately 19.0 percent (2.29 hours) of the spring grazing time took place at night.

Table 2. Means and standard deviations for daily activities of individual cows during three grazing seasons

Activity	Winter 1971-72[a]	Winter 1972-73	Spring 1972
	(hours per day)	(hours per day)	(hours per day)
Grazing	9.22 ± 0.93	9.45 ± 0.97	12.02 ± 0.78
Ruminating			
Standing	0.52 ± 0.56	0.63 ± 0.26	0.34 ± 0.31[a]
Lying	0.15 ± 0.34	8.30 ± 0.94	2.30 ± 0.41[a]
Idle			
Standing	0.94 ± 0.50	1.11 ± 0.65	0.93 ± 0.07[a]
Lying	0.03 ± 0.09	3.93 ± 1.06	0.72 ± 0.26[a]
Travelling	0.30 ± 0.38	0.53 ± 0.60	0.82 ± 0.36
Miles travelled	3.29 ± 1.06	3.89 ± 1.27	4.38 ± 0.92
Drinking	0.03 ± 0.04	0.05 ± 0.06	0.09 ± 0.05
Nursing	----	----	0.55 ± 0.09
	(number per day)	(number per day)	(number per day)
Defecations	6.60 ± 0.74	6.60 ± 1.40	10.50 ± 0.85[a]
Urinations	2.33 ± 0.49	2.73 ± 0.59	3.90 ± 0.74[a]

[a]Data from day-light observations only.

Two grazing patterns were evident in both seasons, intensive grazing and desultory grazing. Intensive grazing occurred during the morning (7:30 a.m. to 11:00 a.m.) and evening (2:30 p.m. to 6:00 p.m.) grazing periods. During these times, the cattle walked very slowly, taking several bites of grass between each step. They often consumed an entire clump of grass before moving to the next one. If disturbed, they quickly resumed grazing. Desultory grazing occurred during the mid-day period of intermittent activities. While grazing in this manner, the cattle took several steps between bites. In fact, they sometimes travelled over 100 yards without stopping to graze. They often appeared to merely nibble at the plants or spent considerable time selecting seed-heads and fall regrowth. When disturbed, they often travelled for quite a distance or stood idle for several minutes before they resumed grazing. When the time spent in these other activities exceeded one minute, it was recorded in the respective activity category. If it was less than one minute, it was included in the grazing time.

The daily grazing times reported here for the two winter periods are well within the range of data demonstrated by other researchers (see Table 1). Grazing times for the spring period are higher than those reported in any previous study. This is perhaps due to two reasons: (1) The cattle were placed on the study site during the month of April to "eliminate the 'wolf-plants' and old plant growth present on the seeding" (Showe, 1972). This suggests the relatively low palatability of the vegetation and the relatively low abundance of new spring forage which was present on the area during this grazing period. The cattle had to spend much time foraging to obtain sufficient nutrients. (2) The higher energy demands of lactation during the spring probably also contributed to the differences in grazing times. The production of milk for calves requires approximately a 30 percent increase in energy intake by cows (Cook, 1970). The higher grazing times reported by other researchers also coincided with less available forage due to high stocking rates (Peterson and Woolfolk, 1955) or periods of lactation (Gonzalez, 1964). Ruminants are known to increase grazing time as a compensatory response to reduced forage supplies or increased energy demands (Arnold, 1970).

Rumination

Rumination was the second most important activity in terms of the time it occupied. During an average 24-hour period in 1972-73, 8.93 hours (37.2 percent of the time) were spent ruminating. The majority (93.0 percent) of the rumination took place at night while the cattle were lying down. During this time, they lay quietly, often with their eyes closed. They sometimes ruminated for two hours at a stretch without pausing to rest or change positions. The remainder of the rumination (0.63 hours) occurred in short periods at irregular intervals throughout the cow-day.

Nocturnal rumination during the 1971-72 grazing period was not recorded. Daytime rumination followed the same irregular pattern observed in 1972-73. It occupied only 0.67 hours daily. Due to the similarity in the daily routines of the two periods, it can most likely be assumed that nocturnal rumination was also similar for the two years.

The cattle ruminated for 2.64 hours during each cow-day in the April 1972 period. This was 1.95 hours more than during an average cow-day in the winter. This difference may be partially attributed to the relationship between forage intake and rumination. Increased forage consumption required an increase in rumination (Duckworth and Shirlaw, 1958). Most of this rumination occurred during the intermittent mid-day period.

The ratio of ruminating time to grazing time for the 1972-73 winter period was 0.94. This ratio as calculated from the data of Herbel and Nelson (1966) was 0.81, from Pearson-Hughes and Reid's (1951) results it was 0.99, and from Dwyer's (1961) study it was 1.08.

An attempt was made to count the average number of chews required per bolus, the average time spent chewing each bolus, and the average number of boli chewed per hour. However, the majority of the rumination occurred at night, and daytime rumination periods were brief and irregularly spaced. Thus, it was impossible to obtain accurate estimates of these parameters without disturbing the animals.

Time spent idle

The cattle spent an average of 5.04 hours (21.0 percent of the time) idle during each 24-hour period in 1972-73. They were lying down for 3.93 hours of this time and standing for 1.11 hours. Idle time during daylight hours was 0.88 hours. In 1971-72, when only daylight observations were recorded, 0.97 hours were spent idle each cow-day. While lying, they usually had their eyes closed. They sometimes stretched their heads out on the ground for 5 to 30 minutes. It appeared that they were asleep much of the time while lying idle, especially during the night. During the majority of the time spent standing idle, they stood quietly with their eyes closed, broadside to the sun or head downwind. The time spent rubbing on plants or steel posts, engaging in pushing contests, and jostling for a place at the water trough is also included in the standing idle time.

In the spring, the cattle stood idle for 0.93 hours and lay idle for 0.72 hours during each cow-day. Approximately 0.77 hours more total time was spent idle during each cow-day in the spring than in the winter. They did not appear to orient themselves to the sun or wind while idling. The moderate spring temperatures and breezes apparently did not dictate such action.

Traveling

The cattle traveled for an average of 0.53 hours (2.2 percent of the time) each day in 1972-73 and for 0.30 hours (1.2 percent of the time) each day in 1971-72. This included all periods when the cattle walked or ran for more than one minute without stopping or taking a bite of forage. Approximately 70 percent of the travel time both years occurred while the cattle traveled to and from water. The remainder consisted of seeking bedding sites, walking for brief periods while grazing, or seeking forage after an idle period.

An average of 3.89 miles were traveled each day by the cattle during the 1972-73 winter season and 3.29 miles during the 1971-72 winter season. This difference was not statistically significant. No attempt was made to record the distance traveled during the nocturnal grazing periods. However, the cattle did not travel far from their beds on any of these occasions. The distance traveled at night was, therefore, relatively short.

The cattle spent 0.82 hours traveling daily in the spring. They also traveled a greater distance daily, 4.38 miles. These differences were most likely linked to differences in drinking activities, coupled with the higher energy requirements of lactation. The time spent traveling to and from water comprised 70.5 percent of the total travel time. This percentage is practically identical to that of the winter period. Occasionally, a cow spent some time wandering about looking for her calf at nursing time, but this did not amount to a significant increase in either travel time or distance traveled during any observation period.

The routes traveled by two typical cows are depicted in Figure 5. One of the cows traveled to water, the other did not drink.

The total distance traveled daily during the winter periods was approximately the same as the reported in comparable studies (Box,

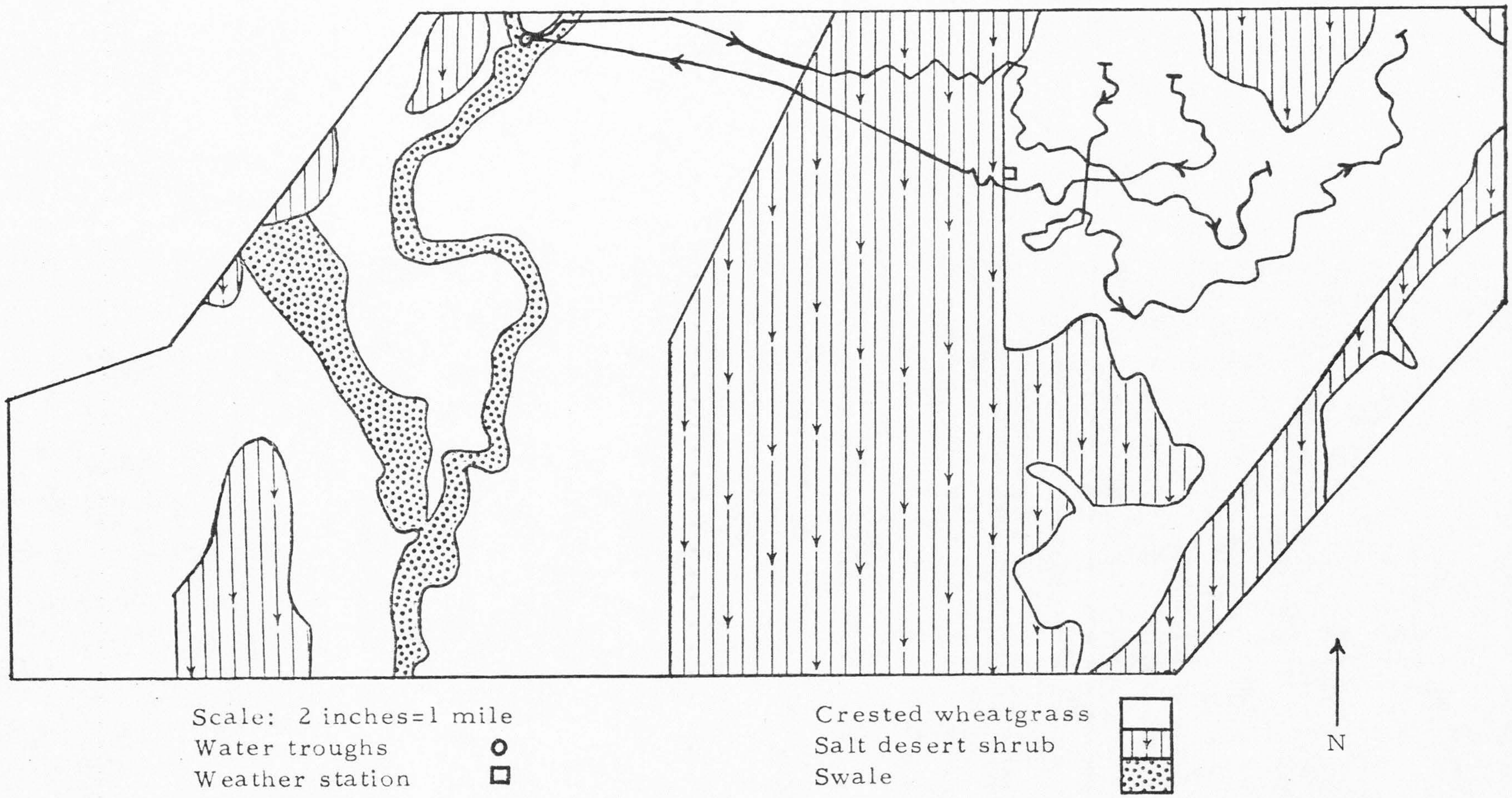


Figure 5. A map of the study area southwest of Snowville, Utah, showing the routes traveled by two cows on two typical days.

Brown, and Liles, 1965; Dwyer, 1961; Gonzalez, 1964; Sneva, 1970). Even though the distance traveled daily in the spring was 0.18 miles more than that traveled by the exercised steers in Gonzalez and Butcher's (1962) study, it was probably below the range that would cause a decrease in milk production or weight gains.

Drinking

The cattle spent an average of 0.05 hours (3 minutes) drinking daily in the winter of 1972-73. This becomes more significant when one considers that only 7 of the 15 observed cows drank during the 24-hour observation periods, for an average of 0.47 drinks per day per cow. This occurred even though fresh running water was available in the troughs at all times.

In the 1971-72 winter period, the cattle averaged 0.03 hours drinking daily (1.8 minutes), but, again, only 7 of the 15 cows drank. Cows were observed sipping water from puddles twice during this period. They were also observed eating snow on numerous occasions both years. This is the only study known to this reasearcher in which the cattle did not drink at least once daily. This unique finding is discussed in a later section in conjunction with the effects which snow depth had on cattle activities.

The cattle drank an average of 1.3 times daily in the spring and spent an average of 0.09 hours daily in this activity. Nine of the ten observed cows drank.

Defecations

The cattle defecated 6.60 times daily during both the 1971-72 and the 1972-73 grazing periods. Six defecations occurred during the cow-day and 0.60 each night. They defecated once upon arising each morning, and approximately every 1.9 hours throughout the cow-day. The majority of the defecations, 70.0 percent, occurred while the cattle were grazing, 22.2 percent while they were standing idle, 4.4 percent while traveling, and 3.4 percent immediately after drinking. All of the nocturnal defecations were during the intermittent activity period around midnight.

The cattle defecated 10.5 times daily in the spring, 3.9 times per day more than in the winter. The probable increased forage consumption due to the higher energy demands of lactation no doubt accounted for this difference.

The daily defecation rate in the winter was lower than that reported by most researchers. It is considerably less than the 11.5 defecations per day reported by Julander (1955) as a guide in determining grazing use by cattle on deer ranges. However, it is considerably higher than the rate of 2.5 defecations per day under winter conditions reported by Box, Brown, and Liles (1965), and identical to the 5-7 per day range reported by Herbel and Nelson (1966). The daily defecation rate of cattle is apparently extremely variable, depending upon the environmental conditions and forage conditions under which the study is conducted.

Urinations

Approximately 2.3 and 2.7 urinations were recorded for each 24-hour period in 1971-72 and 1972-73, respectively. The cows usually urinated soon after arising in the morning, again towards the end of the morning grazing period, and a third time shortly before commencing the evening grazing period. Nocturnal urinations in 1972-73 were recorded at the rate of 0.4 per night.

Urinations during the spring grazing period occurred 3.9 times daily, 1.12 times more than in the winter. The greater water intake and higher energy demand probably explains this difference.

As was the case with the daily defecation rate, the number of urinations per day reported by different researchers is variable. It is apparently more dependent upon environmental conditions and physiological status of the animals than are the other activities. Comparisons between studies based on this parameter evidently require a more sophisticated approach than was possible here.

Calf Activities

Calves approximately 5-10 weeks in age were present on the site during the April 1972 grazing period. These calves spent most of the time frolicking together or sleeping in the sun within 150 yards of their mothers. The older calves occasionally nibbled at succulent grass leaves and sipped water from the troughs, but most of them were content with nursing milk for their subsistence. They nursed 3.67 times daily for a total of 0.55 hours. Each nursing period lasted approximately 10 minutes.

Role of Climatic Conditions in Causing Deviations from the Normal Daily Winter Routine

The extent to which individual climatic factors influenced cattle activities was difficult to ascertain from a strictly statistical point of view. Their influence seemed to be a complex of simultaneously interacting variables, rather than one of independent and unrelated factors. The following discussion will, therefore, be more descriptive than strictly objective in nature. Considering that both climatic measurements and observations of cattle activities during the 1972-73 grazing period were considerably more complete than those of the other two study periods, only the data for that period were used to ascertain the relationship between climatic changes and cattle behavior. Measurements of climatic factors for each 24-hour observation period are tabulated in Table 3. Table 4 contains correlation coefficients and regression equations that express relationships among climatic variables and behavioral responses.

Temperature

The maximum air temperature during the study period was 46° F and the minimum was - 30° F. Temperatures reached a daily average maximum of 29° F at about 2:00 p.m. and fell to an average daily

Table 3. The mean air temperature, magnitude of change in barometric pressure, mean windspeed, snow depth and net amount of solar radiation recorded on the study area during each observation period (Missing values are results of instrument malfunction.)

Date	Mean air temperature (°F)	Magnitude of change in barometric pressure (inches of mercury)	Mean windspeed (miles per hour)	Snow depth (inches)	Net solar radiation (langleys per day)
11/24	26.1	---	0.93	0	95.9
12/2	24.9	---	1.07	0	63.9
12/2	34.2	-0.11	0.43	0	161.1
12/6	15.9	-0.40	---	4.5	---
12/10	-10.7	+0.05	0.50	6.5	143.4
12/18	23.1	-0.02	1.00	7.0	150.0
12/22	31.4	-0.30	3.29	6.5	84.4
12/26	20.4	-0.13	2.72	6.0	177.0
12/30	23.0	+0.14	2.72	6.0	173.8
1/8	11.7	+0.03	---	6.0	176.0
1/12	28.2	-0.03	2.57	10.0	31.9
1/16	---	-0.15	2.29	7.0	167.9
1/20	16.2	+0.26	4.79	11.0	215.6
1/24	9.8	-0.08	---	10.0	204.0
1/29	10.6	-0.24	---	10.0	187.9

Table 4. Product moment correlation co-efficients and regression equations among daily cattle activities and climatic factors

Variables	Correlation co-efficient	Regression equation
Grazing time--mean air temperature	+0.638*	y = -16.085 + 4.782X
Grazing time--change in barometric pressure	+0.557*	y = - 0.618 + 0.083X
Grazing time--mean windspeed	+0.286ns	------
Grazing time--Webster's Chill Index	+0.615ns	------
Distance travelled--mean windspeed	-0.895**	y = 6.190 - 0.996X

*significant at .05 level of probability

**significant at .01 level of probability

nsnot significant.

minimum of 8^{o} F between midnight and 5:00 a.m. The air temperature rose above freezing during but 3 of the 15 observation periods.

The average daily temperature directly affected the total time spent grazing. Correlation analysis indicated a significant ($p \leq 0.05$) and relatively high relationship between these two variables (see Table 4). A regression analysis of these data showed that for every decrease of 1^{o} F in the average daily temperature, there was a decrease of 0.20 hours spent grazing daily (see Table 4).

This relationship can be demonstrated further by separating the observation periods into "cool" days and "cold" days. "Cool" days were defined as those during which the average temperature remained above the critical temperature of the cattle. "Cold" days were those during which the average temperature dropped below their critical temperature. The critical temperature for cattle in this study was considered to be approximately 10° F, as calculated by the methods of Webster (1970) and Young (1971). The cattle spent an average of 9.81 hours grazing on cool days, and 7.97 hours grazing on cold days. This shows a deviation of approximately -1.84 hours of grazing time on cold days.

The differences in grazing time were attributed to three voluntary alterations in behavior. On the extremely cold days the cattle commenced grazing at the average time of 7:56 a.m., 26 minutes later than normal. They ceased grazing at the average time of 5:38 p.m., 21 minutes earlier than the end of the normal cow-day. The time spent idle on cold days was 6.64 hours, 1.60 hours more than the average for the entire period. Much of the increased idle time was spent standing broadside to the sun. The cattle also tended to graze with their sides to the sun when the temperature was low. These behavioral responses were evidently attempts to reduce metabolic heat loss by confining grazing to the warmer part of the day and decreasing the heat lost through surface radiation exchange.

Although the air temperature remained below freezing the majority of the time, the water troughs did not freeze completely.

Running water, constantly entering the troughs, kept an ice-free area approximately 2 feet square open at all times. Some members of the herd were observed drinking during every observation period. In fact, the cow under observation on December 10 (the coldest day of the period) arrived at water and drank when the air temperature was only $+10^{\circ}$ F.

Barometric pressure

Barometric pressure ranged from a high of 30.28 inches of mercury to a low of 29.55. There was no apparent cycle or regular pattern to barometric fluctuations. The pressure tended to decrease 12 to 24 hours before a storm and rise during or immediately following it. Cattle responded to sudden changes in barometric pressure by increasing their grazing time. Their response lagged 6 to 12 hours behind the barometric change. This was true of both rising and falling pressure changes. For these reasons, a correlation coefficient was calculated between the absolute magnitude of change in barometric pressure during the 24-hour period from 6:00 p.m. the night preceding each observation to 6:00 p.m. during the observation period and the total time spent grazing during the observation period. A value of $r = 0.557$ (significant at the .05 level of probability) was obtained (see Table 4). Regression analysis of the same data indicated that for every absolute change of 0.10 inches of mercury the cattle spent 1.20 hours more time grazing. Correlations between the time spent grazing and the average barometric pressure during the day and between the time spent grazing and barometric changes during other time periods were not significant.

By dividing the observation periods into "constant" days of an absolute barometric change less than 0.10 inches of mercury and "variable" days when the absolute barometric change exceeded 0.10 inches of mercury, the deviation which occurred in the normal daily routine was determined. The cattle spent an average of 8.39 hours grazing on constant days and 9.87 hours grazing on variable days. The deviation was + 1.48 hours on variable days.

Windspeed

The incessant wind was an important climatic factor in the Snowville area. The topography and vegetation afforded little protection from its buffetting. One would expect that any effects which wind may have on cattle activities would be highly evident in this area.

Through discussions with Randy Shinn and Robert Anderson (1973), it was learned that the windpseed readings obtained from the IBP weather station may not be completely accurate. Due to a possible error during installation of the anemometer's recording mechanism, the windspeeds recorded may only be 50 to 70 percent of the actual values. They felt that the error was constant for all of the recordings, so the data were used "as is" on the assumption that correlations between windspeed and cattle activities would still be valid, although probably biased.

A correlation coefficient of $r = 0.895$ ($p \leq 0.01$) was obtained between the average windspeed during the cow-day and the distance traveled during the same period (see Table 4). Regression analysis of the same data yielded the equation $y = 6.19 - 0.99X$, indicating that for every increase of 1.0 miles per hour in the average daily windspeed, the cattle traveled approximately 1.0 miles less distance. Correlations between average windspeed and other activities were not statistically significant.

Further examination of the data indicated that the effect which wind had on the distance traveled was primarily related to drinking activities. As mentioned earlier, 70.0 percent of the travel time was occupied by trips to and from water. In that the cattle often grazed in the direction of water during much of the morning, and grazed away from water after drinking, it was impossible to differentiate precisely between the distance traveled while grazing and that traveled to obtain water. However, the average distance traveled on days when the cattle drank was 4.91 miles. They traveled an average of 2.99 miles on days when they did not drink, a difference of 1.92 miles. The average windspeed on days when the observed cattle drank was 1.32 miles per hour. On days when the observed cattle did not drink, the wind averaged 3.27 miles per hour, a difference of 1.95 miles per hour. Evidently, the cattle preferred to travel to water on days when the windspeed remained at a minimum, thus, the distance traveled on such days was almost twice that on windy days.

Orientation of the body to the wind was evident in all activities. The cattle preferred to graze, stand, and lie with head downwind. During especially strong gusts (25-30 miles per hour) they ceased grazing and stood with head downwind, or drifted slowly with the wind until it diminished in velocity. If an intense morning grazing period was interrupted by wind, they spent more time grazing during the intermittent mid-day period. Total grazing time, thus, remained essentially unchanged. Moderate winds (less than 20 mph) had no significant effect on the cattle. They merely grazed with the wind or grazed in the swale until it subsided.

Wind and temperature data were combined to produce a wind-chill index after that described by Webster (1971). No significant correlation was found between it and grazing activities.

Precipitation

Cattle activities were observed during three snowstorms. On the first occasion, snow fell lightly and there was no wind. The cattle grazed intently from dawn until the snow began to fall (around 3:00 p.m.). They then became somewhat restless and grazed in a desultory fashion until the storm passed (5:00 p.m.). They then resumed grazing and grazed steadily until dark. They stood ruminating until nearly 7:00 p.m., as though they were reluctant to lie down on the 0.5 inches of new snow.

The second storm began with snow falling rapidly at about 8:00 a.m. The cattle continued grazing intently in a westernly direction until the wind began to blow at 12:00 noon. They then reversed directions and grazed slowly with the wind until it increased to an estimated velocity of 30 miles per hour at 1:30 p.m. (Due to instrument failure, no wind-speed recordings were obtained for that day.) They then ceased grazing and stood with their heads downwind, their nose close to the ground, eyes closed, and back hunched. As the storm abated (at approximately 2:00 p.m.), one by one the cattle shook the snow from their backs and resumed grazing intently until dark. They stood ruminating for approximately 15 minutes before lying down for the night.

The cattle were bedded down in the swale when the third storm began. This storm was one of blizzard intensity. The snow fell rapidly and the recorded windspeed averaged approximately 10 miles per hour, with gusts reaching 30 miles an hour. The cows remained lying idle until 7:50 a.m. They then arose slowly and remained standing in their beds, with backs hunched and nose down, for some 20 minutes. As the wind was blowing up the swale, the cows began to drift and graze slowly in that direction. When the blizzard slowed at about 9:20 a.m., they continued up the swale to the water trough and drank. They stood idle until the wind and snow increased in intensity, then grazed slowly down the swale until the storm passed (at approximately 12:30 p.m.). After standing idle for about 20 minutes, they scattered and grazed very intensively until dark.

The extent to which they bunched together during storms was demonstrated on January 20. A blizzard had blown most of the night, dropping four inches of new snow and drifting it into piles up to two feet deep. Instead of bedding down in groups of 10 to 20 head as usual, the cattle had all drifted together. All 500 cattle were found bunched together in one tight herd where the swale meets the southern fence line (see Figure 1). They scattered out at sunrise and grazed intently the entire day, even though the wind blew steadily.

These observations suggest that falling snow per se probably has little effect upon the animal's behavior, but wind which frequently is associated with storms in the Curlew Valley is the major factor causing alterations in behavior during storms.

Snow depth

The ground was bare when the cattle were placed on the seeding. The snow depth increased with each snowstorm from 0 inches on November 24, to 4.5 inches on December 6, to 7.0 inches on December 18, to a maximum of 11.0 inches on January 20.

It had its greatest influence on drinking activities. The cattle drank once daily until December 6. After that, drinking declined as snow depth increased. The observed animals did not drink at all during the final four observation periods.

An interesting event occurred during the spring grazing period. A spring snowstorm left 0.5 inches of snow on the ground the morning of April 13. The snow had melted by 12:30 p.m., but the cow under observation that day did not drink. This was the only snowstorm during the spring grazing period, and the only day on which the cattle did not drink. This clarifies the effect which snow depth has on drinking.

Rather than eat only the plant parts which extended above the snow, the cattle pushed the snow aside with their tongues and noses to reach the fall regrowth at the base of the crested wheatgrass plants. This constant rooting formed a distinct dirty line around each cow's muzzle just below her eyes. The cattle undoubtedly ate a considerable amount of snow during this process. This perhaps explains why they were able to go long periods without drinking. They probably obtained a large portion of their water requirements from the snow while they grazed. The cows also spent some time scooping snow into their mouths with their tongues each day. This occurred at irregular intervals for very brief periods anytime during the cow-day.

It was evident that the snow made walking more difficult for the cattle. Their walking was slower, with more movement and effort necessary to complete each step. A heavy snow crust formed approximately 7 inches above the ground towards the end of the study period. The manner in which the snow depth and crust influenced the cattle is reflected in the change in daily travel time. While the gound was bare, an average of 1.49 hours were spent traveling daily. From the time snow covered the ground until the heavy crust formed, daily travel time averaged 0.39 hours. With the crust present, the cattle spent a mere 0.19 hours traveling daily. Rather than walk rapidly from place to place, the cattle took their time and grazed as they traveled.

Solar radiation

Radiation data on the site itself were unavailable. Consequently, recordings taken at the IBP Ecology Compound in Snowville were used. The amount of net solar radiation received per day averaged 143.8 langleys. The maximum per day for the period was 215.6 langleys, and the minimum was 31.9 langleys. No significant correlations were found between the daily radiation readings and individual cattle activities. However, it was evident that the initiation and cessation of the cow-day during this study period was governed quite closely by daylight. Although the exact time varied (as influenced by temperature, and wind, and precipitation), the cow-day always began within one hour preceding sunrise and ended within one hour following sunset. Squires (1971) has suggested that a certain threshold light intensity triggers initiation and cessation of daily activity in grazing sheep.

Orientation of the body to the sun was also manifested by the cattle. The first time the sun's rays impinged directly on the cattle each day, they interrupted grazing to stand idle, broadside to the sun, for several minutes to one hour. This activity occurred even when the sun was obscured by clouds until late in the afternoon. Within five minutes after the sun broke through the clouds, the cattle would turn broadside to its rays and spend some time apparently basking in its warmth. An average of 0.64 hours (73.0 percent of the total time spent standing idle during daylight hours) was spent in this fashion each day.

The cattle also tended to graze with their sides to the sun when it was shining brightly and the wind was relatively calm. This behavior probably aided them in maintaining their body temperature by decreasing the net loss of heat energy through surface radiation exchange.

Humidity

The hygrothermograph in use at the IBP weather station tended to malfunction at temperatures below freezing. Therefore, complete and accurate recordings of relative humidity were obtained for only three of the observation periods. These recordings were practically identical. The relative humidity rose to a maximum of 70 percent at approximately 2:00 a.m. each night. It then decreased steadily after sunrise to a low of 50 percent about 2:00 p.m. each afternoon. Although these figures appeared to be relatively constant and typical of the entire study period, the recordings were insufficient to warrant the forming of assumptions or conclusions concerning the effects which fluctuations in the relative humidity had on cattle activities.

Relationship of Behavior Modification to the Total Energy Cost of Cattle Activities

Some researchers (Irving, 1964; Hafex, 1968) have hypothesized that cattle modify their behavioral routines to minimize energy loss during periods of climatic stress. To investigate this hypothesis, a time-energy budget for cows during the average 24-hour period of the 1972-73 winter grazing period was calculated (Table 5). This budget

Table 5. Activities and energy expenditures by 340 kg. cows during the average winter day (1972-73)

Activity	Quantity	Unit energy cost	Total energy cost	Percent of total
Grazing (hours)	9.45	0.84 kcal/hr/kg[a]	2698	58.0
Standing (hours)	2.30	0.34 kcal/hr/kg[b]	266	5.7
Ruminating (hours)	8.93	0.24 kcal/hr/kg[b]	729	15.7
Traveling (km.)	6.26	0.45 kcal/km/kg[c]	958	20.6
Total net energy expenditure for activity			4651	100.0

[a]From Graham (1964) and includes cost of harvesting, prehending, and swallowing forage (0.54 kcal/hr/kg) as well as the cost of standing associated with grazing (0.34 kcal/hr/kg).

[b]From Graham (1964).

[c]From Brody (1945).

presents estimates of the energy cost of the major daily activities. When evaluated from the standpoint of how changes in various behavioral patterns might modify the total daily energy expenditure, possible cause-effect relationships may be suggested.

The energy cost involved in standing comprised a relatively small proportion (5.7 percent) of the total daily energy budget. As the cattle spent 73.0 percent of the daily standing time with the body at right angles to the sun, it is possible that much of the energy cost of this activity was directed toward body temperature maintenance.

This was a minor modification in behavior when the entire daily energy budget is considered and perhaps explains why no significant correlations existed between the time spent standing and climatic variations. Possibly more sophisticated methods of measuring the surface radiation exchange between the cattle's coats and the atmosphere would detect any such correlations. The radiation measurements obtained in this study were certainly lacking in many respects, preventing detailed evaluation of this relationship.

The activities which comprised by far the major proportion of the total daily energy expenditure were grazing, traveling and rumination. As the duration and tempo of rumination evidently depend in part upon the quantity and quality of forage intake (Loffgreen, Meyer, and Hull, 1957) and also upon inherited characteristics (Hancock, 1953), one would expect little direct change in rumination activities as a result of climatic variations. Indeed, that was the case in this study. Correlations between the time spent ruminating and climatic fluctuations were all statistically insignificant.

The daily energy cost of traveling comprised 20.6 percent of the total daily energy expenditure. A decrease in the time spent traveling would, therefore, result in a considerable decrease in total energy expenditure. This would explain the significant negative correlation which existed between average daily windspeed and the time spent traveling. Snow depth and drinking activities apparently did have some influence upon the time spent traveling daily, but the relationship between windspeed and heat energy loss through convection probably exerted a more profound influence on this activity. The cattle attempted to conserve their body heat energy by not traveling to water on windy days. They apparently preferred to supplement their water requirements by eating snow until they could travel to water on a relatively calm day.

Grazing was the most costly activity in terms of energy expenditure. It comprised 58.0 percent of the total daily energy cost. This indicates the degree to which any change in the time spent grazing would have on the daily energy budget. The correlation (see Table 4) which existed between grazing time and air temperature demonstrates the extent to which the cattle modified their grazing activities in order to aid in energy conservation. Decreasing air temperatures, especially those below the animals' critical temperature, caused the cattle to decrease their grazing time in an attempt to avoid excessive heat loss. Snowstorms combined with wind also caused the cattle to reduce the time spent grazing. Snowstorms were not of sufficient numbers or duration to be analyzed statistically in this study, but their effect on the daily energy budget is obvious.

Decreased grazing during periods of cold stress would result in a lower energy intake. This would apparently offset any benefits from decreasing grazing time in order to conserve energy. To resolve this apparent conflict, one must consider the relationship between changes in barometric pressure and the time spent grazing. As indicated, any notable change in barometric pressure correlated significantly with increased grazing time. Barometric changes of considerable magnitude invariably occurred preceding or following periods of snowfall, lower air temperatures and/or high winds. It is, therefore, postulated that the cattle were able to detect approaching periods of climatic stress by sensing these barometric changes. They responded by intensifying their grazing activities. In effect, they stored energy reserves in the form of ingested forage to prepare themselves to withstand the approaching threat of excessive energy loss. As the energy cost of body temperature maintenance became excessive, they refrained from, or reduced, their grazing until the period of cold stress had passed. When barometric changes and metabolic sensory mechanisms indicated that this period had ended, the cattle once again grazed more intensively for sufficient time to offset the period of low energy intake.

The amount of energy conserved through behavior modification during the 24-hour observation period on December 10, 1972, (the most "stressful" day of the grazing period) was calculated. The energy cost of activity for the observed cow during that day is presented in Table 6, along with the deviations of that day from the daily average for the entire grazing period (see Table 5). The cow under observation conserved approximately 358 kcal. through behavior modification.

Average still air temperature for the day concerned in Table 6 was -10.7^{o} F. Calculations of the animal's critical temperature and the quantity of extra energy required for maintenance of body temperature (Young, 1971) revealed that approximately 331 kcal. of additional energy

Table 6. The energy cost of activity and body temperature maintenance for the cow observed on December 10, 1972, and the deviations of that cost from the daily average for the 1972-73 period

Activity	Quantity	Unit energy cost	Total energy cost	Deviation from average
Grazing (hours)	7.53	0.84 kcal/hr/kg	2150	-548
Standing (hours)	2.98	0.34 kcal/hr/kg	345	+79
Ruminating (hours)	7.02	0.24 kcal/hr/kg	573	-156
Traveling (km.)	8.02	0.45 kcal/km/kg	1225	+267
Total net energy expenditure for activity			4293	-358
Maintenance of body temperature (degree-F days[a])	20.70	16.00 kcal/degree-F day		+331

[a]The number of degree-F days is the difference between the equivalent still air temperature and the estimated critical temperature of the animal.

were required by the cow for body temperature maintenance during the 24-hour period in question. The similarity between the amount of energy conserved through behavior modification and the expended to maintain body temperature during the same period is perhaps indicative of the degree to which cattle may be able to increase energy conservation by modifying their daily routine in accordance with changing climatic conditions.

Use of Vegetative Types

Crested wheatgrass

The crested wheatgrass type received the majority of the cattle use during all three grazing periods. During the 1971-72 period, they were present in this type 80.2 percent of the time. During the April 1972 period, the cattle used the crested wheatgrass 53.7 percent of the time. The cattle grazed and bedded in the crested wheatgrass the majority of the time, but occasionally ventured into the other types for short periods and spent some time drinking and loafing at the waterhole.

During the 1972-73 period, the cattle were present in the crested wheatgrass 66.55 percent of the time. They spent 79.20 percent of their grazing time in this type (Table 7). As it comprised 59.6 percent of the total study area, application of O'Donnell and Walton's (1969) preference formula:

$$\frac{\text{Percent of grazing time}}{\text{Area of type}} = \text{Preference for the type}$$

yielded a preference rating of 1.33 for this type during the 1972-73 period. Grazing occupied the biggest portion of the time spent in this type (Table 8). However, the cattle use in the crested wheatgrass decreased towards the end of the grazing period (Figure 6). It appeared that the cattle preferred to graze in the grass, but as the forage supply diminished, they shifted their use patterns to the other vegetation types. The increasing severity of the winter weather also may have influenced

Table 7. Location, by vegetation type, of each of the seven activities in 1972-73 (Values are percentages of the total time spent in each activity per vegetation type.)

Activity	Crested wheat-grass	Salt desert shrub	Swale	Sacrifice area around water	Totals
Grazing	79.20	8.55	12.25	0	100%
Standing ruminating	69.38	3.01	22.12	5.49	100%
Lying ruminating	58.66	7.77	33.57	0	100%
Standing idle	62.95	5.22	26.31	5.52	100%
Lying idle	56.13	6.07	37.80	0	100%
Traveling	51.98	34.45	13.57	0	100%
Drinking	0	0	0	100.00	100%

this shift from the crested wheatgrass. The grass provided little shelter from the biting winds and freezing temperatures.

Table 8. Activity budgets for four vegetative types

Activity	Crested wheat-grass	Salt desert shrub	Swale	Water
Grazing	46.86	41.38	19.51	0
Standing ruminating	2.73	0.97	2.34	24.41
Lying ruminating	30.50	33.07	46.98	0
Standing idle	4.36	2.96	4.91	43.31
Lying idle	13.82	12.24	25.05	0
Traveling	1.73	9.39	1.22	0
Drinking	0	0	0	32.28
Totals	100%	100%	100%	100%

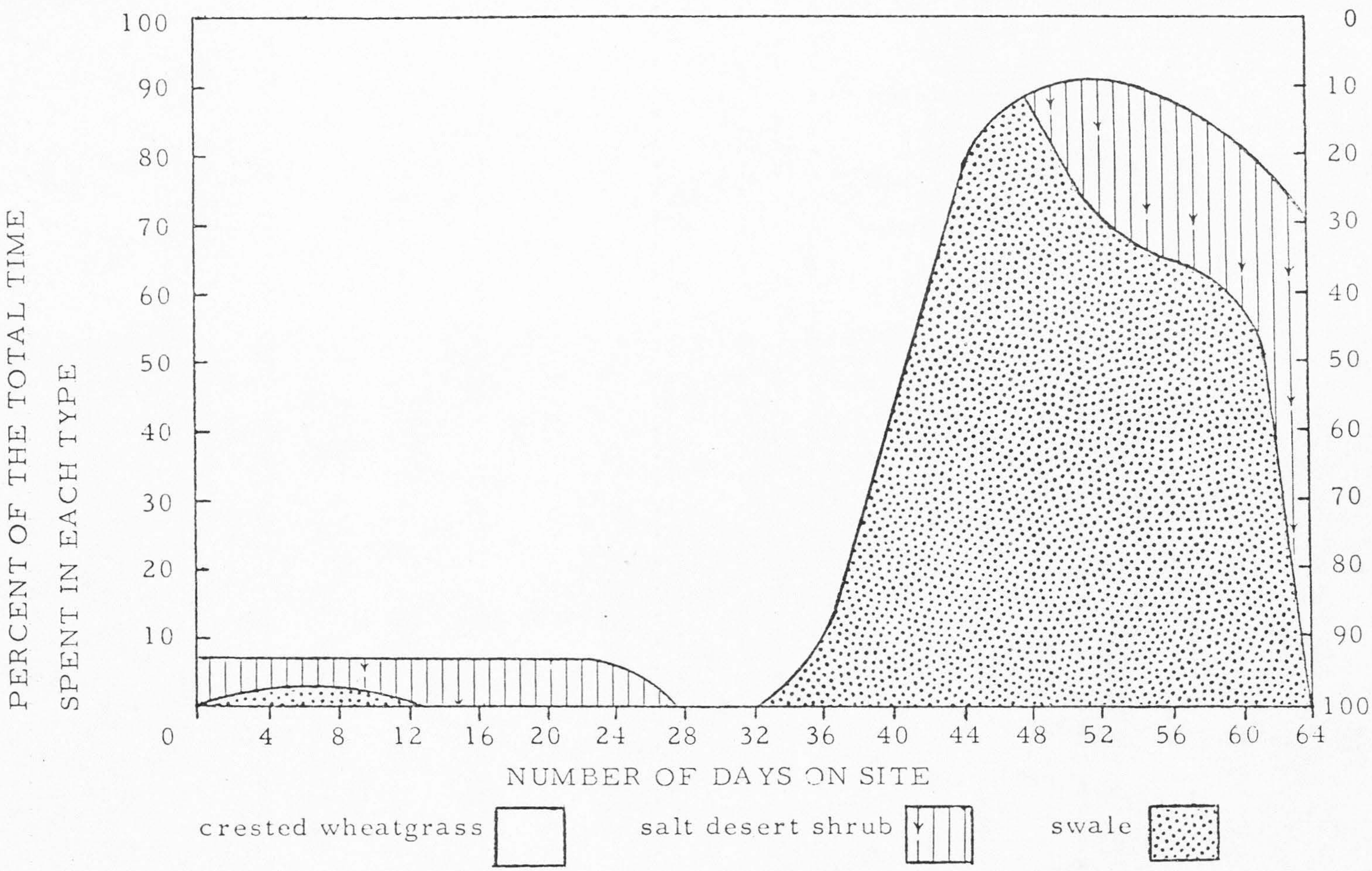


Figure 6. The percent of the total time spent in three vegetative type by the cattle during the 1972-73 winter grazing period.

Swale

During the 1971-72 grazing period, the cattle spent 2.8 percent of their time in the swale. This increased to 4.0 percent during the April 1972 period. During the 1972-73 grazing period, the cattle spent 24.73 percent of their time in the swale. A preference rating of 2.78 was calculated for this type during the 1972-73 period. Although this rating is based on grazing time, it appeared that this type was most valuable as a source of shelter. The abundant big sage brush plants, many of them 4 feet in height, provided relatively good shelter from the severe winter weather. This is further supported by the fact that 72.03 percent of the time in this type was spent lying ruminating or idle (see Table 8). The cattle used this type very little until the latter part of the grazing period (see Figure 6). The most use of this type occurred during and after the severe blizzard described earlier in this paper.

Salt desert shrub

The cattle spent 15.9 percent of the time in the salt desert shrub during the 1971-72 period, and 33.6 percent of the time in this type during the April 1972 period. During the 1972-73 grazing period, the cattle spent 36.0 percent of their time in the salt desert shrub. The preference rating for this type in 1972-73 was 0.24. This value may be biased upward as the cattle had to pass through this type to reach water from the eastern portion of the study area. This is further demonstrated by 34.45 percent of the travel time being spent in this area, while percentage of time engaged in other activities in the are are much smaller (see Table 6). Figure 6 also shows that cattle use in this type was negligible during the major portion of the study period. The cattle began to use it only after the forage was depleted in the other vegetation types. They began eating considerable amounts of big sagebrush and shadscale late in the grazing season. They often broke off whole branches and chewed them until they were devoid of leaves. When the cattle were removed from the area, they appeared to be losing weight rapidly.

Sacrifice area

As would be expected, use of the sacrifice area around the water source was restricted to drinking, standing idle, and standing ruminating. The cattle spent 1.1 percent, 8.7 percent, and 0.59 percent of their time at the water trough during the three successive grazing periods. One-third of this time (32.28 percent) was spent drinking.

SUMMARY AND CONCLUSIONS

The activities of cattle grazing on a partially seeded area southwest of Snowville, Utah, were observed during three grazing periods, the first during the winter of 1971-72, the second during April 1972, and the third during the winter of 1972-73. The time cattle spent in eight individual activities and in various vegetation types were recorded to the nearest minute and a daily routine was established. Climatic variables were quantified during the 1972-73 winter grazing period to assess the role of climatic stress in modification of the daily activity routine.

During winter, two intensive grazing periods occurred daily, one in the morning and another in late afternoon. Desultory grazing occupied the major portion of the remaining daylight hours. The cattle drank 0.47 times daily at the average time of 9:00 a.m. Rumination was generally confined to the nocturnal hours, and occupied the major portion of the night. Nocturnal grazing occurred around midnight until a snow cover had accumulated. This grazing period was then replaced by a period of intermittent activities. The cattle grazed approximately 9.45 hours, ruminated 8.93 hours, were idle 5.04 hours, traveled 0.53 hours, and spent 0.05 hours drinking during an average 24-hour period. They defecated 6.60 times and urinated 2.53 times daily. Each cow traveled an average of 3.59 miles daily.

The daily activity routine during the spring grazing period differed in that three intensive grazing periods occurred, one in the early morning, another in the evening, and a third around midnight. The cattle drank 1.3 times daily at the average time of 8:45 a.m. The mid-day hours were spent intermittently idling, ruminating, and grazing in a desultory fashion. The calves were nursed four times daily, once at 6:20 a.m. and approximately every six hours thereafter. The majority of the rumination apparently took place after dark, but could not be quantified due to the wariness of the cows with young calves. The cattle grazed approximately 12.02 hours, nursed their calves 0.55 hours, and spent 0.09 hours drinking during each 24-hour period. During the cow-day, they ruminated 2.64 hours, were idle 1.65 hours and traveled 0.82 hours. They defecated 10.5 times and urinated 3.9 times daily. An average distance of 4.38 miles was traveled daily. The greater tempo of grazing, drinking, and traveling activities in spring was attributed to the more temperate climatic conditions and the higher energy demands of lactation.

Statistically significant positive correlations were detected between the time spent grazing each day and the average air temperature and between the time spent grazing each day and the absolute magnitude of change in barometric pressure. A negative correlation existed between the distance traveled each day and the average windspeed during that day. These correlations were attributed to attempts by the cattle to conserve body heat energy by modifying their behavior. The energetically most expensive activities (grazing and traveling) were modified to the greatest degree.

Other behavioral alterations were also noted. The distance traveled daily decreased as snow depth increased. Frequency of drinking also decreased with increasing snow depth. Precipitation in the form of snow combined with excessive wind caused the cattle to cease grazing and drift with the storm. The cattle oriented themselves at right angles to the sun and/or head downwind while standing and lying.

Use patterns of the vegetative types varied. The cattle spent the majority of the time in the creasted wheatgrass, but evidently preferred to graze and bed down in the swale later in the grazing period. They also sought shelter from severe storms by remaining in the swale for the duration of the sorm. The native salt desert shrub was not used extensively until the forage supply in the other types was evidently exhausted.

The major conclusion from this investigation was that cattle modify their behavior in conjunction with changes in various climatic factors. These modifications are directed toward the conservation of energy during periods of cold stress.

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APPENDIX

Table 9. The weights in pounds of 23 cows placed on the Snowville seeding from November 15, 1971, to January 21, 1972

Ear tag no.	Nov. 15 weight	Jan. 21 weight	Loss or gain	
231	820	775	45	
232	690	665	25	
233	635	630	5	
234	750	735	15	
235	645	660		15
237	725	700	25	
238	980	990		10
239	650	650	0	
240	675	650	25	
241	1020	980	40	
242	860	820	40	
243	665	650	15	
244	730	725	5	
245	890	937		47
246	630	645		15
247	700	650	50	
248	650	635	15	
249	645	630	15	
250	660	665		5
251	950	935	15	
252	990	920	70	
253	700	665	35	
254	695	675	20	
		Average loss	19.7 lbs/head	

Table 10. Cattle activities[a] during the November 15, 1971, to January 20, 1972, grazing period

Date	Grazing	Ruminating standing	Ruminating lying	Idle standing	Idle lying	Traveling	Miles traveled	Drinking	Defe-cations	Urina-tions
11/18	10.82	0.50	0	0.43	0	0.28	3.44	0.05	6	2
11/23	9.83	0.13	1.02	0.53	0.18	0.25	3.87	0.03	8	2
11/24	9.39	0.17	0.93	0.38	0.33	0.13	3.12	0	5	2
11/30	9.45	0.95	0.27	0.37	0	0.25	3.25	0.08	7	3
12/6	7.17	2.20	0	0.70	0	1.03	3.16	0	6	2
12/8	9.32	0.05	0	0.35	0	0.30	5.00	0.08	7	2
12/11	9.90	0.22	0	1.17	0	0.12	3.22	0	6	2
12/17	8.97	0.20	0	1.55	0	0.02	2.19	0	7	3
12/22	9.54	0.78	0	0.73	0	0	2.56	0	7	2
12/23	8.70	1.00	0	1.10	0	0.28	3.05	0.07	7	3
12/29	9.37	0.67	0	1.03	0	1.25	5.30	0.08	7	2
1/6	9.14	0.33	0	1.32	0	0	1.92	0	7	2
1/8	8.78	0.13	0	1.77	0	0	2.17	0	7	3
1/11	7.60	0.23	0	1.80	0	0.62	4.86	0.10	6	3
1/15	10.25	0.18	0	0.93	0	0	2.25	0	6	2
Means	9.22	0.52	0.15	0.94	0.03	0.30	3.29	0.03	6.60	2.33

[a] Daytime observations only.

Table 11. Cattle activities[a] during the April 1972 grazing period

Date	Daytime grazing	Nocturnal grazing	Rumination standing	Rumination lying	Standing idle	Lying idle	Travel time	Miles traveled	Drinking	Daytime nursing	Nocturnal nursing	Defecations	Urinations
4/8	10.00	2.50	0	1.83	0.98	1.23	0.35	2.70	0.08	NC[b]	NC	10	3
4/11	9.85	2.25	0.08	2.28	0.92	0.80	0.43	3.22	0.08	NC	NC	10	3
4/13	8.99	---	0.33	2.34	1.25	0.90	0.60	3.75	0	0.27	---	11	4
4/15	7.51	3.17	0.52	3.14	1.28	0.67	1.45	5.56	0.12	0.27	0.16	11	4
4/18	11.53	1.97	0	1.82	0.32	0.43	0.58	4.22	0.05	0.43	0.15	9	3
4/20	9.89	---	1.05	1.84	0.88	0.57	0.83	5.00	0.15	NC	NC	12	4
4/22	9.28	2.17	0.30	2.45	1.10	0.50	1.33	5.25	0.15	1.47	0.16	11	5
4/25	10.69	1.75	0.35	2.57	0.77	0.37	1.02	4.87	0.08	NC	NC	10	5
4/27	10.07	---	0.37	2.34	0.80	0.90	0.73	4.78	0.12	0.45	---	10	4
4/29	9.63	2.27	0.35	2.35	1.02	0.82	0.85	4.50	0.10	0.45	0.15	11	4
Means	9.73	2.29	0.34	2.30	0.93	0.72	0.82	4.38	0.09	0.39	0.16	10.5	3.9

[a]Nocturnal observations include grazing and nursing only.

[b]NC signifies "no calf."

Table 12. Cattle activities[a] during the 1972-73 grazing period

Date	Grazing	Ruminating standing	Ruminating lying	Idle standing	Idle lying	Traveling	Miles traveled	Drinking	Defe-cations	Urina-tions
11/24	10.03	0.58	7.40	0.38	4.02	1.52	4.98	0.07	9	4
11/28	10.77	1.05	8.03	0.35	2.32	1.43	5.08	0.05	8	3
12/2	9.90	0.23	7.98	0.75	3.50	1.53	6.80	0.10	9	3
12/6	10.22	0.70	8.82	0.73	3.47	0.07	3.20	0	8	3
12/10	7.53	0.70	6.32	2.28	6.20	0.88	4.98	0.08	7	2
12/18	9.18	0.40	7.23	2.33	3.73	1.02	5.17	0.10	6	3
12/22	10.07	0.37	9.62	1.05	2.80	0.10	2.69	0	7	3
12/26	10.10	0.82	8.72	0.87	3.50	0	2.62	0	6	3
12/30	9.98	1.02	8.95	0.10	3.58	0.27	3.61	0.10	7	3
1/8	9.20	0.87	8.25	1.10	4.58	0	2.25	0	5	2
1/12	8.38	0.68	7.30	1.63	5.12	0.70	3.73	0.18	6	3
1/16	9.90	0.57	9.10	0.77	3.62	0.05	3.80	0	6	2
1/20	10.12	0.62	8.87	1.22	3.18	0	2.56	0	5	2
1/24	7.67	0.18	8.30	1.68	5.80	0.37	3.53	0	5	3
1/29	8.70	0.63	9.68	1.35	3.58	0.05	3.31	0	5	2
Means	9.45	0.63	8.30	1.11	3.93	0.53	3.89	0.05	6.60	2.73

[a] 24-hour observations.

VITA

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