# Activities of Domestic Sheep on Central Utah Ranges

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# ACTIVITIES OF DOMESTIC SHEEP ON CENTRAL UTAH RANGES

by

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ABSTRACT

Activities of Domestic Sheep on

Central Utah Ranges

by

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The range sheep industry, economically important to Utah and to the United States, produces needed food and fiber from much of the less productive land. Improved management will depend on more knowledge of the range ecosystem. Research to determine the time spent by sheep in activities of differing energy demands and to determine what factors affect sheep activity was completed on Utah ranges.

The research was conducted in central Utah on foothill range near Eureka and on mountain range near Scofield. Rambouillet sheep were loosely herded on the sagebrush-aspen areas on mountain range and were unherded on foothill range where they were assigned to 14 pastures. Activities on foothill range were studied in May and June at two grazing intensities on three species of seeded wheatgrasses and on native sagebrush-juniper range. Feeding, standing ruminating, standing idle, lying ruminating, lying idle, and traveling were recorded as all-inclusive activities by observing the behavior of four randomly selected sheep from among marked ewes at 90 instantaneous scans at 10-minute intervals from 0500 to 1950 hours on each of 28 days at each location. Hourly readings were made on the degree of cloudiness, wind movement, ambient temperature, and relative humidity.

Data were analyzed to determine components of variance and to evaluate effects of month, grazing intensity, and kind of forage. Each activity was regressed on environmental factors in a stepwise-deletion multiple regression procedure.

Sheep daily repeated a bimodal routine of early morning feeding followed by midday ruminating and resting which lasted until late afternoon, followed by feeding again before bedding down at nightfall on high ground. On mountain range the morning and afternoon feeding periods were of similar length, but on foothill range the sheep began feeding earlier in the afternoon and thus fed longer in the afternoon than during the morning hours. Sheep were highly synchronous in their choice of activity.

Sheep spent more time feeding on seeded foothill range than on either native foothill or mountain range. Conversely, they spent more time lying ruminating and standing idle during the daylight hours studied on mountain and on native foothill range. Traveling time was greater on mountain than on foothill range, but the horizontal distances traveled were the same at both locations. Sheep spent more time lying idle on native foothill range than on seeded pastures. At the spring foothill location the sheep also spent more time standing idle and traveling in May than in June. No differences were noted in any activities between intensities of grazing.

The daily feeding time of sheep responded positively to average daily temperature. Both lying ruminating and lying idle showed positive regressions on relative humidity. Traveling and standing idle were negatively related to mean daily temperature, which varied only within a narrow temperate range and averaged 20 C during the two periods of study.

Sheep activities necessary to the animal on a daily basis were little affected by small changes in the range environment. Feeding time was proportional to the estimated energy expenditure for maintenance, activity, and production at each location.

(149 pages)

# INTRODUCTION

## Nature and Justification of the Study

The range sheep industry is of significant economic importance to the state of Utah and to the United States. As of January 1, 1979, there were 8.24 million breeding ewes in the United States and 338,000 breeding ewes in Utah (Crop Reporting Board, ESCS-USDA 1979). The country also produces 45.55 million kg of wool annually and the state of Utah more than 2 million kg. Though these data represent a decline of about 60% in the past 12 years, increases in recent lamb and wool market prices reflect the continuing demand for these sheep products.

More than one-fourth of all land in the United States is in range and grassland pasture with grazing the largest single use of agricultural land. In the range sheep area of the western United States, including Utah, 70% of the privately owned range is in only fair or poor condition, while public lands are estimated to be producing only half or less of their potential. The USDA Land and Water Policy Committee (USDA 1962) concluded that pasture and range research to develop suitable management systems for the many different types of vegetation, livestock, and game should be accelerated and that more research was needed on nutrition of animals and man as affected by properties of soil, plants, and climates.

Range scientists have long recognized that proper management to eliminate wasteful practices could play a significant role in increasing sheep production on western ranges (Doran 1943). Johnstone-Wallace and Kennedy (1944), Peterson and Woolfolk (1955), Skovlin (1957), and

Nelson and Furr (1966) recognized that a thorough knowledge of the behavior of grazing animals was essential for the proper understanding of the application of range management principles. Animal watching can suggest ways and means of amending the animal's environment so that the grazing animal may find a better diet for itself and step up its own production on different types of range and under different weather conditions.

Squires (1976a) indicated that animal behavior is concerned with the observable characteristics of the movements and expressions of the animals and the underlying neurophysiologic processes and could thus provide a firm basis for sheep management. Weaver and Tomanek (1951) concluded that one should study the activities of livestock as they graze and travel naturally on the range to observe what they do and insofar as possible, determine why they do it. Tribe (1950) noted that investigations of different individual animals and different species under a wide variety of soil and pasture conditions at different elevations, and during a great variety of climatic conditions. Such studies are essential for the development of management which properly accounts for the behavior of sheep on range to improve efficiency of energy utilization.

## Objectives of the Study

This investigation was conducted to provide needed information for improved management of sheep on western rangelands. Specifically, I set out to:

1. Estimate the time spent by ewes in specified activities on

central Utah range under typical foothill and mountain conditions and,

2. Test the following hypotheses;

   a. Sheep spend the same amount of time in specified activities on both foothill and mountain range.

   b. Sheep spend the same amount of time in specified activities on native and seeded foothill range.

   c. Sheep spend the same amount of time in specified activities on three selected seeded species of wheatgrass.

   d. Stocking pressure has no effect on sheep activities on foothill range.

   e. The time ewes spend daily in specified activities is not affected by changes encountered in selected environmental factors.

# LITERATURE REVIEW

## Related Studies

At the time the field work was done the nearest parallel to the present study was reported by Doran (1943). He observed activities and grazing habits of sheep on summer range in the aspen zone of western Colorado. He recorded behavior over a 3-year period as occasions arose, amassing at least 17 observations for each of the 29, 30-minute intervals from 0500 to 1950 hours. For each observation period Doran selected some landmark beforehand, and then choosing the ewe nearest that landmark at the selected time, recorded her activities continuously for the next 30 minutes. He recorded time spent feeding, traveling, resting, drinking, nursing, and salting.

While my studied was being conducted, Bowns (1971) was studying activities of unherded sheep on range in Iron County, Utah. He observed an individual ewe through her active day. Activities reported included grazing, resting, traveling, watering, and salting. Bowns was unable to separate ruminating and idling time because an individual sheep could not be kept in view continuously under his conditions. He did find that Rambouillet ewes traveled farther than did Columbia ewes.

Squires (1974) in Australia recorded the activities of ten or so flock leaders every five minutes during the active day. In one 24-hour observation with warm temperatures and a full moon, he noted no grazing or traveling at night. He divided time among grazing, resting, and walking. Squires (1976b) also compared sheep activities on grassland with that of sheep on saltbush range.

Several workers studied cattle activities under conditions somewhat similar to this investigation. Gonzalez (1964) followed individual cows continuously for 24-hour periods on mountain range in northern Utah, yet he treated his data as number of 10-minute intervals for statistical analysis. Activities recorded were feeding, standing ruminating, lying ruminating, standing idle, lying idle, and walking, plus urinating and defecating. Malechek and Smith (1976) recorded cattle activities in northwest Utah on sagebrush and seeded grass range by following individual cows continuously for 24-hour periods. They related activities to weather conditions and calculated energy expenditures for the daily routine. Cows consumed less energy on cold days but spent less energy in activities thus deferring energy expenditures until warmer days.

## General Behavior of Sheep

The behavior of animals including sheep has been summarized by several reviewers (Scott 1945, 1946; Tribe 1950; and Hafez and Scott 1962). Scott (1956) listed nine behavioral categories which encompassed all animal activities as contactual, ingestive, eliminative, sexual, epimeletic, et-epimeletic, agonistic, allelomimetic, and investigative. He also compared sheep and mice (Scott 1945) and noted the great development of allelomimetic behavior in sheep, which should draw animals together and influence group formations in their social organization. Tribe (1950) probably wrote the most thorough review of the literature on behavior of grazing animals to that time.

The review by Hafez and Scott (1962) is a better combination of the knowledge of both ethology and livestock activities.

They listed examples of sheep activities in each of the behavioral categories. Also, they gave estimates of sheep activities including total grazing time (9-11 hours per day), total rumination time (8-10 hours), and distance traveled (3-8 miles). Hafez and Scott also reported the average number of chews per rumination (39,000), chews per minute (91), chews per bolus (78), and number of boli per day (500). In reference to social organization of sheep they noted that in the ordinary activity of grazing, sheep flocks show little or no sign of dominance. They further suggested that farm or range flocks are comparatively disorganized but are protected from the natural consequences of disorganization by fencing and herding.

Animal performance may be affected by changes in feeding behavior in response to established social relationships. Bond et al (1967) found a strong social relationship to develop between steers and sheep when grazed in pairs with the strength of this relationship increasing with time.

Dudzinski and Arnold (1967) noted that ewes with lambs were more widely spread while grazing than were flocks of wethers. Dudzinski, Pahl, and Arnold (1969) found that average flock size, group size, and number of groups changed with changing environment while average distance to nearest neighbor and between groups did not change. Squires (1975b) noted different group sizes in sheep grazing homogeneous saltbush pasture and heterogeneous grassland pasture. He indicated the group size was affected by heterogeneity of the environment with more varied environments leading to smaller group size (Squires 1975c).

Hunter (1954, 1962, 1966a, 1966b) extensively described the behavior of hill sheep in Scotland.

He noted periods of rest related to times of sunrise and sunset during the long days from April to September (Hunter 1954). Sheep began to move from high ground before sunrise, and after a period of grazing in the course of moving to and after arriving at the low ground, they rested for one or two hours then began to graze again. He observed another period of rest in the afternoon which was less general in that the sheep did not all rest at approximately the same time. In the late afternoon the sheep began to move up the hill and started to settle down shortly before sunset. From October to March, however, the sheep grazed the high ground during the day.

Hunter (1964b) indicated that on hill pasture each sheep moved daily over a well-defined group of plant communities of different types of vegetation. As the younger animals tended to follow their dam and travel over the same area as the dam the basic unit within a flock was the family unit. Several family units together formed higher groups similar to wildlife home range groups as described by Burt (1943). Members of a home range group did not necessarily share the same daily movement although some sites were shared. Thus the home range group was the highest natural order of grouping, and what the rancher calls a flock is an economic and administrative artifact. Hunter (1964b) stated that the pasture was not a common environment for the sheep, who divided into subflocks composed of families of sheep restricted to parts of the pasture which differed in elevation, aspect, and vegetation as determined by patterns of behavior.

Ruckebush (1972) reported that sheep slept less than 4 hours daily; they spent 84% of the day in a wakeful state. Sheep spent most of the wakeful period in an alert condition, while cows spent much of their wakeful state in a drowsy condition. Balch (1955) stated that under normal conditions of management, healthy adult cattle and sheep, probably ruminants in general, sleep little if any at all. He suggested that if sleep does occur it can only be of a very light and transient nature. He thought that this peculiarity of ruminants may be related to the need for maintaining the thorax in an upright position for proper functioning of the reticulo-rumen and to the requirement of time and consciousness for rumination. Recently Meddis (1975) suggested that sleep serves the function of maintaining immobility in animals at times when immobility is an optimum behavioral survival strategem and that sleep is not for recuperation.

## Activities of Wild Sheep

Studies of wild sheep may assist in understanding the behavior of their domestic counterparts even though domestic sheep may have lost much of their original sensitivity to the environment as noted by Squires (1975a). Reed (1959) showed that most Old World Sheep belong to several subspecies of *Ovis ammon*, while the North American wild sheep are subspecies of *Ovis canadensis* of far eastern Siberia. Apparently domestication of sheep occurred in southwestern Asia in prehistoric times, and Bradley (1968) states that hybridization evidence suggests combining all recent sheep of the world including domestic sheep *Ovis aries*, into one species *Ovis ammon* with appropriate subspecies.

Honess and Frost (1942) reported that bighorn sheep in Wyoming left their bedgrounds at an early hour, but later in the winter than summer, and sought one of their favorite bedgrounds each evening. The sheep, which ruminated and idled in midday for several hours, only occasionally drank water and seemed indifferent to water when grazing in high mountains in the summer. They found that the bighorn's morning and afternoon grazing periods were not as regular as that of wapiti (Cervus canadensis) and deer (Odocoileus hemionus).

Wilson (1968) found that desert bighorn (Ovis canadensis nelsoni) travel more and unpredictably where water was deficient, but he also concluded that succulence of plants was more important than temperature in determining their free water needs. From his study with wild sheep, he indicated that sheep which bedded down under his observation were almost always within 100 m of where they bedded down on the following morning. During the midday ruminating and idling period desert sheep often arose and grazed for awhile before again lying down.

Spencer (1943) found that practically all feeding by bighorn sheep in Colorado was done during the day, especially during the winter, and at night they bedded down in rough, sheltered areas. The sheep were found grazing at all hours of the day and, where forage was plentiful, the feeding bouts were rather short and interrupted by periods of rest.

## Livestock Activities

Cory (1927) observed cattle, sheep, and goats in Texas continuously from the time they began grazing each morning until they ceased grazing each night. Thus recorded, sheep had an average day of 13.2 hours, spending 6.6 hours feeding, 2.0 hours lying resting, 1.3 hours standing ruminating, and 1.4 hours idling per day. Cory found that in pastures of less than one section (260 hectares) the sheep traveled 5.1 km each day and spent 1.7 hours traveling other than while feeding. In comparison, cattle were active 13.6 hours per day with 7.6 hours devoted to feeding. Other activities of cattle included 1.4 hours traveling (4.4 km), 1.6 hours lying resting, 1.2 hours standing ruminating, and 1.4 hours idling.

Wagnon (1963) kept individual cows under continuous surveillance for 33, 24-hour days. He found cows fed for 10.8 hours, ruminated 7.7 hours, rested 3 hours, and idled 38 minutes each day. He noted that of the 32% of the day in rumination, 64% was done at night. Furthermore, 80% of the rumination was done while lying, 17% while standing, with the remainder while nursing the calf or walking.

Dwyer (1961) recorded a cow day from the time the cow began grazing each morning until she bedded down in the evening of 15.3 hours with 52% or 7.96 hours of feeding. Resting time was 6.74 hours, divided between 4.26 hours standing and 2.48 hours lying. Rumination time was 4.75 hours, likewise divided into 2.48 hours standing, 1.92 hours lying, and 0.33 hours walking. During the day cattle traveled an average of 4.2 km. Only four and eight minutes, respectively, were devoted to watering and salting. Dwyer also found that cattle fed about 1.7 hours each night, beginning near midnight.

Tribe (1949a) noted that between 1900 and 0700 hours cattle grazing was unpredictable (not regular) and most occurred before 0100 hours. Smith (1959) reported one peak of night grazing and stated that nighttime grazing was constant at 20% of total feeding time for cattle in Rhodesia.

Hubbard (1952) found cattle in shortgrass prairie of Canada to have average days of 16.8 hours. He recorded 10 hours feeding, 4.6 hours resting, 1.6 hours idling, and 49 minutes ruminating. The cattle also traveled 54 minutes each day to move 3.76 to 5.5 km.

Under continuous observation, 4 steers spent 7 hours feeding, 1.4 hours standing ruminating, 4 hours lying ruminating, 5.5 hours standing idle, 6 hours lying idle, and 0.1 hours drinking per 24 hours (Hull, Lofgreen, and Meyer 1960).

Nelson and Furr (1966), working with small groups of cattle for 24 hours per day, reported times of 600 minutes feeding, 171 minutes standing ruminating, 368 minutes lying ruminating, 156 minutes standing idle, 118 minutes lying idle, and 27 minutes walking. Herbel and Nelson (1966) noted similar values for two breeds of cattle on New Mexico range except more time was spent walking. Gonzalez (1964), working with cattle in northern Utah recorded similar values for these activities with 638 minutes grazing, 493 minutes ruminating, 250 minutes idling, 20 minutes walking, and 39 minutes nursing of calves.

Bowns (1971) in southern Utah compared the grazing activities of 3 breeds of sheep, which spent about 268 minutes feeding each morning and 326 minutes feeding in the afternoon. He found that sheep spent more time grazing late in the season with a concomitant decrease in resting time. Squires (1976b) found that sheep grazing in Australia also increased their grazing time as well as the time they spent walking to water as the summer season progressed. At the same time resting was declining as a percentage of the active day.

The distance sheep traveled while grazing was measured directly with rolling wheel devices in New Zealand and Utah (Cresswell 1960, Cresswell and Harris 1959). On hill pastures Cheviot sheep ranged 10.7 km per week and Romney about 6.7 km per week. On Lowland pastures the Cheviot traveled 13.1 km and the Romney 10.7 km per week. In Utah, Rambouilett ewes in a 1-2 hectare pasture averaged about 2 km of travel per day.

## Ingestive Functions

Pearce (1965) stated that there was no direct evidence on what initiates rumination, but that apparently the presence of roughage itself was not sufficient to promote immediate rumination. Pearce and Moir (1964) reported that grinding animal feed resulted in shorter retention in the digestive tract and lower apparent dry matter, organic matter, and crude fiber digestibility. Restricting rumination with a tight muzzle to prevent chewing markedly increased retention time and was accompanied by higher apparent digestibility of these fractions.

Gordon (1958) conducted a detailed analysis of rumination behavior of a caged yearling ewe with a jaw movement measuring apparatus. Rations,fed for 6-7 days each, consisted of combinations of hay and concentrate meal from 100% hay to 100% meal. When hay was fed there was no relationship between the quantity of hay ingested and the amount of rumination, which averaged 8 hours per day. Without hay in the ration rumination fell to only 2.5 hours per day and much of this was pseudo-rumination. Rate of chewing during rumination varied from 83-99 chews per minute, compared with 42 chews per minute for cattle, for a total of 39,000 chews per day. He also found that tiring during rumination was expressed not in reduction of chews per minute but rather in a longer rest between boli. Such rest periods accounted for 15% of the total rumination time.

Iggo (1951) indicated that the cycle of contractions of the reticulum and rumen in unanesthetized sheep were periodic, recurring every 50-70 seconds and consisting of a sharp double contraction of the reticulum followed immediately by a contraction of the rumen. Iggo postulated that there is a region in the brain of the sheep caudal to the intercollicular plane which can maintain coordinated activity of the reticulum and rumen. Duncan (1953) stated that the normal, rhythmic activity of the rumen and reticulum, and propulsion of digesta from these organs into the omasum and abomasum, are lost following total vagotomy. Splanchnotomy, however, had no significant effect on gastric emptying and motility and did not appear to modify the effects of concomitant vagotomy in the sheep.

Sheep eat to a constant distension of their digestive tracts measured by the "fill" which is in turn determined by the rate of passage of the food and its digestibility according to Blaxter, Wainman, and Wilson (1961). Voluntary intake of long fodders by sheep and their resultant gains of body weight were positively related to the apparent digestibility of feed energy. Neither taste nor acceptability to the palate determined intake. Purser and Moir (1966) found ad libitum intake of dry matter of poor quality bulky roughages to be proportional to the rumen volume. Animals with small rumens fed longer causing a more continuous and possibly relatively more active type of metabolism. They thought that sheep with smaller rumens might be more efficient when feed intake was restricted.

The animal's rumen capacity and the rate at which undigested feed could be moved through the alimentary canal limited production in cows given feeds with low digestibility (Conrad 1966). At high levels of digestibility the physiological state of the cow was the primary determinant of feed intake. Conrad suggested that physical limitations on eating capacity vanish and the influence of production become dominant at some point which varies with body size, production and fecal excretion rate. Pigden and Bender (1972) suggested that above about 65% digestibility, bulk no longer controls the intake of forages. Below 65%, bulk is a major but variable factor which can be modified by grinding. Such grinding would reduce the time and energy required for particles to pass through the rumen due to increased surface area, rate of rumen fermentation, density of feed, and the resulting effective capacity of the animal.

Tribe (1952) stated that the action of an animal in rejecting or accepting a food assigns to the food a degree of palatability and must in the ultimate stage be explained in terms of special sensory reactions. He noted differences between the preferences of the same animal at different times, and felt that food selection depended on an animal's nutritional history. He concluded that since food selection of an animal today may be influenced by what it chose yesterday, preference was a function of the animal rather than of the plant.

Krueger (1970) found that learning was important in the selection of diet by sheep, as sheep new to an area changed from a grass diet to a forb diet after five days on the new area. Working with sheep with senses selectively withdrawn on range pastures, he concluded that taste was important for food rejection with smell supplementary to taste.

Sight was used for positive selection of species preferred by other senses. Krueger suggested that sheep selected plants by sight but moved on if selection was not reinforced by positive preference by other senses. Tribe (1949b) also found that the sense of smell was important in the initial stimulation of appetite but, because of its adaptive character, smell could only be of supplementary importance in influencing the food selection of the grazing sheep.

Tribe and Gordon (1949) discovered that sheep failed to associate either a red or blue color with the palatability of their food and concluded that sheep were color-blind. Reflecting on these problems of voluntary intake and their own research, Peterson and Woolfolk (1955) suggested that for optimum welfare, range managers should provide ample forage for the necessary fill, thus leaving preferably more than half the time free for rest and rumination by the sheep.

## Influence of Pasture Situations

Attributes of the pasture may affect the grazing activities of sheep and other livestock. Hubbard (1952) found no significant difference in time spent in different activities due to rate of stocking, but distances traveled by cattle appeared to be clearly related to the size of the field. Cresswell (1960) found that variations in the size of the lowland pastures did not result in proportional variations in the distances traveled each day by Romney and Cheviot sheep. A several-fold increase in the size of hill pastures resulted in both breeds increasing their distances by about one-third.

Hancock (1954) noted that grazing time of twin dairy heifers increased with scarcity of forage and decreasing quality. Rumination time was prolonged by poor quality grass.

Peterson and Woolfolk (1955) reported that length of time spent grazing and distance traveled by cattle on short-grass range appeared related to intensity of utilization and to the variety of vegetational types. Smith (1959) reported no difference in grazing time between two groups of cattle at two grazing intensities in Rhodesia during the dry season. During the rainy season the heavy grazing group spent about 43% more time grazing than the lightly stocked group, and Smith concluded that the 13 hours of grazing during the dry season might be a practical limit to which grazing time could be increased to compensate for lack of forage.

The difficulty in obtaining green forage in late spring may have increased the time spent grazing by cattle in Colorado, but the time spent at certain daily grazing habits was mostly a function of day length (Reppert 1960).

Arnold (1960) noted differences among sheep in their ability to increase their grazing time. He found a linear increase in grazing time as forage availability decreased, but that the rate of increase in grazing time was insufficient to maintain liveweight. Rumination time became less as forage availability declined. The linear increase in grazing time was more closely associated with green dry matter than to total dry matter on offer (Arnold 1964). Grazing time began to decrease when there was less than 560 kg per hectare of green dry matter on the *Phalaris*-annual grass-subterranean clover pasture. Intake per hour of grazing increased rapidly as available forage increased, reaching 200 g organic matter per hour at 2800 kg per hectare.

Iskander (1973) noted differences in feeding habits of sheep between moderate and heavy stocking only at a 20% significance level. Sheep used objects to orient themselves while grazing with utilization occurring in strips from one object to another. The sheep thus grazed more heavily around shrubs and objects placed in the pasture.

Squires (1973) noted that sheep bedded in thickets of 1-2 m tall Atriplex on saltbush range and under trees in grassland range. Squires (1975b) found that sheep without shade will hold their heads in the shade of other sheep. When resources such as shade and water are localized, limitations to group size occur. Grazing sheep formed smaller groups on grassland than on saltbush range. Squires (1976b) reported that sheep grazing on saltbush drank three times as much water as sheep grazing grassland. Sheep which drank twice rather once daily traveled more and grazed areas more than 3 km from water even though passing by areas of abundant forage closer to water.

## Response to Climatic Factors

Armstrong et al (1960) reported that Scottish Blackface and North Country Cheviot sheep did not differ between breeds in response to temperatures as long as fleece lengths were similar. At 32 C fleece length had no effect on heat production, at 20 C metabolism increased unless fleece length exceeded 18 mm, and at 8 C metabolism rose unless fleeces exceeded 35 to 40 mm.

Blaxter et al (1959a) found that sheep with fleeces were content at ambient temperatures of 11 to 30 C. Heat production was constant between 15 and 35 C indicating that sheep with fleeces have a very wide thermoneutral zone rather than a point of minimum heat production or critical temperature. They concluded that heavy fleeces depress the critical temperature and reduce the effects of drops in temperature below the critical level. Also, the heat produced by sheep from metabolism of its food and the heat it loses in warming its food and water to body temperature were thought to be very important items in determining the critical temperature. At temperatures above 30 C the sheep panted, and heat losses by vaporization of water converged to one value at 40 C irrespective of fleece length. Studies of the insulation of the fleece indicated that, above the critical temperature, heat loss from hair-covered areas, especially the ears, was three-fourths of the total while loss from fleece-covered areas was minimal.

Working with closely clipped sheep, Blaxter et al (1959b) noted that sheep shivered at temperatures below 23 C and that the first reaction to cold was corrugation of skin due to contraction of the fascial muscles. They found that respiratory frequencies were proportional to increasing heat loss by vaporization. They concluded that below the critical temperature the increase in heat production with falling environmental temperature reflected the increased radiative losses of heat while increasing heat production above the critical temperature appeared related to the inefficiency of the evaporative mechanism. Voluntary intake of water and urinary volume increased with a rise in environmental temperature, but only a small amount of cooling resulted from warming large quantities of water to body temperature. They concluded that changes in body heat content might explain heat losses due to rapid changes in air temperature of as much as 20 C in 1-3 hours.

Knapp and Robinson (1954) reported that both the Jersey cow and the Corriedale ewe showed an increase in body temperature, respiratory rate and volume, and respiratory and transcutaneous water losses during heat exposure. In the sheep respiratory water losses reached one-third of the total water loss. Thus the ewe was relatively a poorly sweating ruminant relying mainly on the respiratory mechanism for approaching a heat balance. Brook and Short (1960a, 1960b) agreed that panting was the principal method of evaporative cooling in sheep. They found that evaporative cooling by sweating, above the critical temperature, was important to closely clipped sheep but was of limited value to the fully fleeced animal. Schmidt-Nielson (1964) reported that the thick fleece was excellent protection against heat flow from hot environments and that its removal greatly decreased the tolerance to high temperature.

Symington (1960) compared the climatic adaption of Merino, Persian, and a native hair breed of sheep in Rhodesia. The Merino's fleece stabilized its skin temperature, but that of other breeds did not. Also the Merino fleece did not aggravate the effects of exercise and did not hamper elimination of heat from the body after exercise. Respiratory evaporation was the principal thermolytic process, but heat tolerance in the Merino was due primarily to insulation by the fleece and not to more efficient physiological thermolysis, since unshorn Merino ewes showed more and shorn Merinos less effective body temperature regulation than the other breeds.

Stimulation of temperature receptors in both the nasobucal area and elsewhere on the general body surface is necessary for the normal respiratory response of sheep to a raised environmental temperature (Bligh 1959). Receptors on the general body surface are more effective. The onset of panting in response to an abrupt rise in environmental temperature need not be preceded by any change in deep body temperature. Bligh (1959) concluded that any changes in deep body temperature coincident with the onset of panting were passive and that panting resulted from stimulation of peripheral thermal receptors. Alliston and Ulberg (1960) recorded only a slight rise in rectal temperatures from 39 C to 40 C between environmental temperatures of 21 C and 32 C for ewes at 65% relative humidity, while respiratory rates climbed from 64 to 136 per minute.

Gonzalez (1964) found no effect of maximum daily temperature on walking distances of cattle on northern Utah range. Cattle sought tree cover from rain and hail storms, where they remained standing until resuming grazing 20-30 minutes after the storm ceased. He noted that cattle ruminated primarily in shade during the day but mostly in the open at night.

Ehrenreich and Bjugstad (1966) recorded a high correlation between grazing time of heifers during summer days and a calculated temperature-humidity index. Cattle grazed less as the index increased under summer heat stress conditions.

Malechek and Smith (1976) recorded more time spent grazing by cattle on Utah winter range on warm days than on cold days. At the same time the cattle spent less time standing. They grazed and ruminated longer following absolute changes in atmospheric pressure. Distance traveled was inversely related to wind velocities.

Bennett (1972) stated that sheep preferred to stand when exposed to cold, even though standing cost them more energy.

Squires (1973) noted increasing water intake and frequency of watering with rising temperatures in studies of sheep in Austrailia. Above 38 C the Merinos abandoned their afternoon walk to water thus consuming less water daily while reducing distance traveled. Squires indicated that sheep grazed into the wind three-fourths of the time and bedded down during midday to reduce heat stress. Start of morning grazing was closely related to sunrise; cessation of afternoon grazing was less closely related to sunset. Squires (1974) noted that time of feeding by sheep was related to changing seasons and length of day as summer progressed and not related to increasing temperatures. Length of afternoon grazing increased as season progressed with its later sunsets. Squires (1976b) found that wind direction affected the area grazed by sheep in treeless saltbush pastures, but sheep on grassland ruminated and idled in the shade of trees in the downwind corner of the pasture.

## Energy Expenditure of Grazing Animals

Osuji (1974) stated that increased energy requirement for animals on range might be due to the energy cost of eating, walking to graze, and the "work of digestion" done by the gut in handling bulky forage. He found that the metabolizable energy requirement of sheep given fresh grass was 12% higher than that of sheep given dried grass. He indicated that the cost of eating is a direct function of time spent eating.

Young (1966) found no difference in energy cost of eating between whole and fistulated sheep in which feed was recovered by esophageal canula. He concluded that metabolic rise and cost of eating must be related to the work of prehension and mastication. Christopherson and Webster (1972) recorded a 60% increase in oxygen consumption during eating with rapid fall thereafter.

Graham et al (1959) reported on critical temperatures of closely clipped sheep fed grass cubes at three levels--600, 1200, and 1800 g per day. Minimal heat production occurred at 39-40 C for the lowest feeding level, 33 C for medium feeding level, and 24-27 C for the highest feeding level. They found that below the critical temperature, heat production increased at a constant rate per surface area per degree Celsius irrespective of feeding level and at 8 C was more than double the minimum metabolism determined at the medium feeding level. Above the critical temperature heat production increased exponentially with rectal temperature, with a doubling of metabolism for each 9 C increase in rectal temperature.

Osuji (1974) indicated that the energy cost of ruminating was very small compared to eating or other activities of sheep. He suggested that the value of rumination may be in the saving of energy during rumination as opposed to eating. Rumination might save sheep eight hours of grazing time per day and the additional energy required to graze for that period.

Brockway (1965) and Brockway, Pullar, and McDonald (1969) studied the effects of postural changes on heat content and energy expenditure of sheep in metabolism chambers. They observed that from the overall average, skin temperature at 40 sites on the body showed a mean decrease of 0.14 C when standing and a mean increase of 0.13 C when lying. Likewise, body core temperature showed changes of -0.13 C when standing and +0.04 C when lying. Bennett (1972) noted that heat loss in the lying position was 80-90% of the heat loss while standing. He suggested that the extra energy expenditure while standing, a typical response of sheep to cold stress, might be the best strategy for short periods of cold.

Graham (1964, 1965) concluded that muscular effort accounts for more than 40% of the energy expenditure at maintenance of a 50 kg grazing sheep but represents only 11% of that of a caged sheep. He measured expenditures as metabolizable energy in kcal per hour per kg of body weight due to various functions . Expenditures were: ruminating 0.24, standing 0.34, and either eating prepared meals or grazing 0.54. Varying intake rates from 60 g to 800 g per hour did not affect energy expenditure. Thus a grazing animal might have energy requirements 40% greater than those of a caged sheep and walking distances could substantially increase this difference.

Blaxter (1967) reported energy expenditures in kcal per kg metabolic weight per 24 hours for fasting sheep of varying ages and also for certain activities. Basal energy expenditures decreased with age of sheep, averaging 59 kcal per kg metabolic weight per 24 hours for the animals studied. He indicated that sheep in fasting and calorimetry experiments spent 21 of 24 hours lying; standing cost them an additional 2.8 kcal per kg metabolic weight per 24 hours.

Young and Corbett (1972) recorded increasing grazing time with declining herbage per hectare, and they found that grazing sheep had 60-70% higher energy requirements than caged sheep.

Osuji (1974) calculated a 36% higher energy requirement for a grazing sheep over the resting metabolic rate and a 28% higher energy cost for a grazing sheep as compared to one fed prepared meals under housed conditions.

Clapperton (1964), Corbett et al (1969), and Cook (1970) have all reported energy requirements for walking both horizontal distances and vertical climbs. Clapperton (1964) noted expenditures of 0.59 cal per horizontal m per kg of body weight and 6.36 cal per vertical m per kg of body weight for varying speed and feed levels with sheep. Corbett et al (1969) reported similar data for horizontal travel and slightly higher requirements, 7.2-7.9 cal/kg wt, for vertical movements. Cook (1970) applied previous work to western range sheep situations. He assumed 33 kcal per 100 pounds per mile on level walking and downhill travel plus 59.4 kcal per 100 pounds per mile uphill on a 5% slope. Typical energy expenditure for travel by sheep on mountain range was assumed to be 100 kcal energy per day considering a mile downhill plus a mile uphill each day for average size ewes.

Osuji (1974) using a similar technique arrived at a cost of 180 kcal per day for sheep walking 6.1 km per day under a grazing situation. His calculated values for a grazing sheep in kcal per day were 1200 for resting metabolism, 202.5 for grazing, 12 for ruminating, 36 for standing, and 180 for travel for a total estimated energy expenditure of 1630.5 kcal per day.

## Methods of Previous Studies

Previous students of livestock behavior have utilized a number of methods of observation and recording of activity as well as measures of environmental factors. Cory (1927) recorded the primary activity of a flock of sheep on a continuous basis. Doran (1943) noted the activity of a single ewe continuously for 30-minute periods. Dwyer (1961), Gonzalez (1964), Bowns (1971), and Malechek and Smith (1976) each recorded the activities of an individual animal continuously. Squires (1973, 1974) recorded the activities of the changing group of the 10 or so sheep leading each activity at 5-minute intervals.

Several investigators compared continuous and intermittent observations to determine cattle activities. Harker, Taylor, and Rollinson (1954) compared intervals of 1 to 6 minutes to record activities of 10 cattle by recording the activity of each animal at the instant of observation and not during the interval. They chose the 4-minute interval after a short trial period and recorded grazing, ruminating, idling, walking, drinking, and salting activities. Hull, Lofgreen, and Meyer (1960) compared continuous observation with instantaneous recordings at 15-, 30-, and 60-minute intervals on four steers individually. They concluded that up to 30-minute intervals between instantaneous observations was adequate to report major activities, more frequent observation was required for minor activities, and several animals were needed because of variation among individuals.

Nelson and Furr (1966) observed groups of 7 to 11 beef cows on pasture continuously and at 15-, 30-, and 60-minute intervals. Grazing and rumination times were estimated within desirable accuracy at either

15- or 30-minute intervals. Even 15-minute intervals led to unreliable estimates of the less-time-consuming activities.

Gammon (1976) recorded instantaneous observations of the activities of 4-5 steers individually during the grazing day in Rhodesia.

Box and Pook (1974) used a time sampling method in which the subject's behavior was noted at 10-second intervals cued by a timer. They found it satisfactory to record umambiguous, readily observable, mutually exclusive activities. They suggested that very short activities would be underestimated by the technique and would be better measured by some event-recording method.

Altmann (1974) indicated that sampling decisions are made whenever the student of behavior cannot continuously observe and record all the behavior of all the members of a group and must therefore settle for a partial record. She described instantaneous observation and noted its usefulness to determine the amount of time spent in activities. She suggested that the shorter the intervals, relative to the behavior durations, the closer this method would come to the time spent. Instantaneous observations on each of a group of animals was referred to as a scan-sampling technique. Altmann (1974) noted that scan sampling could provide information on the degree of synchrony among members of the group, but each individual must be scanned for the same brief period of time. Scan sampling was most suited to study of non-social activities. Percent of time could be estimated directly from the percent of samples in which a given activity was recorded.

## STUDY AREAS AND ANIMALS

Sheep activities were studied on foothill range and mountain range in central Utah (Figure 1). The foothill ranges of the area are commonly used for sheep grazing in late spring and in some cases again in the fall, and the mountain ranges are usually grazed in summer.

### Eureka Foothill Site

The foothill study area is located in Tintic Valley between U.S. Highway 50 and the Union Pacific Railroad tracks a few kilometers south of Eureka in Juab County, Utah (Figure 2). The site, administered by the Bureau of Land Management, US Department of the Interior, is operated as a cooperative research area by Utah State University. The area is between 1725 and 1825 m elevation and receives about 330 mm precipitation as an annual average. The amounts received in the summer months are especially low and erratic. Drainage from the gentle slopes is westward across the study site which features silt loam soils.

The study area supports both native vegetation and introduced seeded grasses. The treatments of brush control and seeding were described by Cook (1966). The native vegetation is characterized by a moderately dense overstory of Utah juniper (*Juniperus osteosperma* (Torr.) Little) and dense big sagebrush (*Artemisia tridentata* Nutt.). Principal herbaceous species include cheatgrass (*Bromus tectorum* L.), squirreltail (*Sitanion hystrix* (Nutt.) J.G. Smith), Indian ricegrass (*Oryzopsis hymenoides* (Roem, & Schult.) Ricker), western wheatgrass (*Agropyron smithii* Rydb.), and bluebunch wheatgrass (*A. spicatum* (Pursh.) Scribn. & Smith).

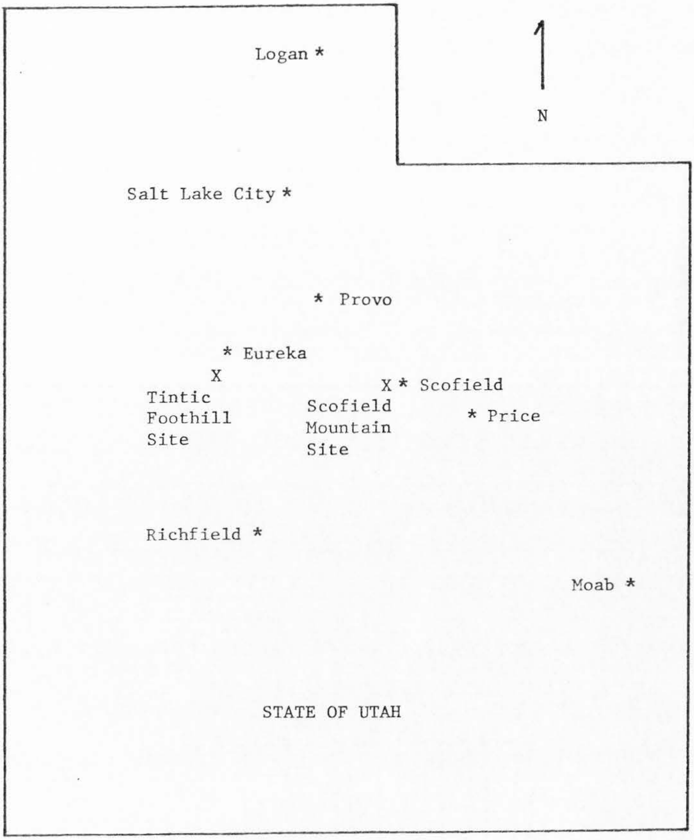


Figure 1. Location of foothill and mountain sites in Utah for sheep grazing activity research.

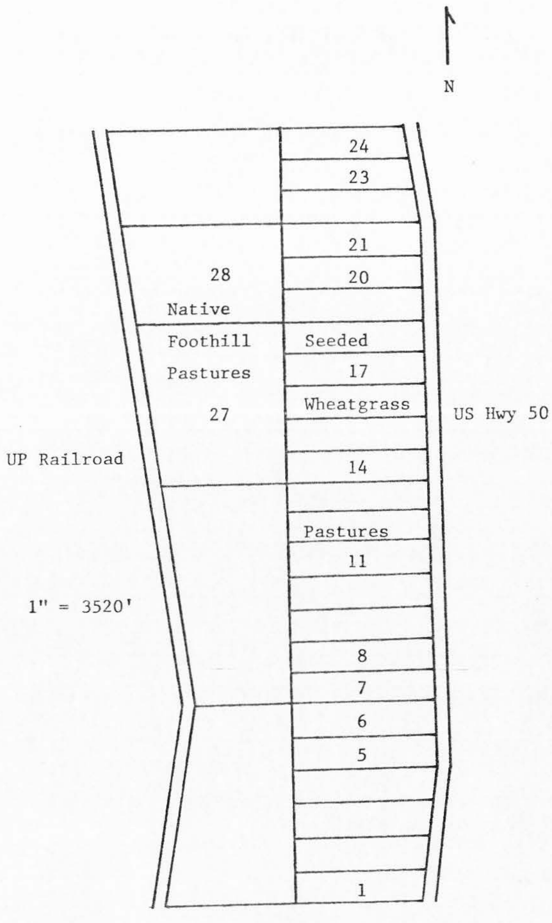


Figure 2. Pasture layout at Tintic Valley near Eureka, Utah, site of spring foothill study of sheep activities.

Brush control treatments began in 1947 at Eureka and starting in 1950, 24 pastures of about 25 ha each were seeded to single species or 3-way mixtures of crested wheatgrass (Agropyron cristatum (L) Gaertn. and A. desertorum (Fisch.) Shult.), intermediate wheatgrass (A. intermedium (Host) Beauv.), and tall wheatgrass (A. elongatum Host). Six control pastures of 100-200 ha along the lower west side of the site remained in native vegetation.

## Scofield Mountain Site

Studies on summer mountain range were conducted near Scofield in western Carbon County, Utah (Figure 3). Elevation ranged from 2360 m at the mouth of Andrew Dairy Canyon at Fish Creek where sheep grazing began in early July to about 2890 m on Granger Ridge on the Manti Division, Manti-La Sal National Forest. The entire area was located west of Scofield, south of Fish Creek, north of Headquarters Canyon, and east of the Carbon-Sanpete county line (T 12 S, R 6 E, Salt Lake Meridian) on the grazing allotments of Euray Allred of Fountain Green, Utah.

Vegetation varied from sagebrush-grass at lower elevations and south exposures through aspen-fir to spruce-fir on north slopes at higher elevations. Vegetation similar to that at the Scofield site has been extensively described by scientists at the Great Basin Experimental Range located near Ephraim some 50 km southwest of the site. Ellison (1954) described several subtypes within the subalpine zone. Precipitation, though not measured on the study area, could be expected to increase by 40 mm per 100 m rise in elevation from about 540 mm at 2360 m to 750 mm at 2890 m (Lull and Ellison 1950).


Figure 3. Topographic map of Scofield mountain range sheep study site with approximate boundaries of area grazed by study herd in both 1965 and 1966.

Major forage species in sagebrush-grass sites included bluebunch and slender wheatgrass (Agropyron trachycaulum (Link) Malte), western yarrow (Achillea millefolium L. ssp. lanulosa (Nutt.) Piper), penstemon (Penstemon spp.), sagewort (Artemisia michauxiana Bess. ), and snowberry (Symphoricarpos oreophilus A. Gray). Other common species were cheatgrass, geranium (Geranium richardsonii Fisch. & Trautv.), cinquefoil (Potentilla fruticosa L.), peavine (Lathyrus spp.), and big sagebrush.

Forage beneath the canopy of aspen (Populus tremuloides Michx.) included mountain brome (Bromus carinatus Hook. & Arn.), Kentucky bluegrass (Poa pratensis L.), slender wheatgrass, vetch (Vicia americana Muhl.), and chokecherry (Prunus virginiana L.). Openings at the higher elevations produced predominately mountain brome and yarrow with scattered elderberry (Sambucus racemosa L.). Gooseberry (Ribes montigenum McClatchie) often occurred as an edge species between aspen and sagebrush sites.

More mesic sites at intermediate elevations were dominated by Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and at higher sites by Engelmann spruce (Picea engelmannii Parry) and subalpine fir (Abies lasiocarpa (Hook.) Nutt.). Little forage grew beneath these dense stands of conifers.

## Sheep and Their Management

All ewes involved in this study were owned by Euray Allred. They were essentially purebred Rambouillet although none were registered (Allred, personal communication). Ewes were wintered on the cold-desert-shrub range in western Utah where they were exposed to rams beginning in early December each year.

In spring the sheep were moved to sagebrush foothill range near the town of Jericho, not far from the Tintic study site. After shearing in late April at Jericho the sheep were moved to the experimental pastures on May 1 just prior to the onset of lambing. About July 1 the sheep with lambs were trailed to mountain range near Scofield where they remained until late September. After the lambs were separated in early fall the sheep spent a few weeks on foothill sagebrush range before trailing to winter range.

At the Tintic study site ewes were assigned to individual pastures prior to lambing. Numbers per pasture varied from 32 to 111 ewes, depending on pasture grazing capacity and the degree of utilization desired (Table 1). A herder checked the ewes daily during lambing in May, except for the pasture under activity observation that day. About June 1 both ewes and lambs were weighed and all dry ewes were removed. To maintain desired utilization dry ewes were replaced by ewes with lambs from similar pastures not involved in the experimental design. All sheep were weighed again before leaving the Tintic site.

At Tintic water was provided in open metal troughs, one in each pasture. Water was replenished daily, and troughs were cleaned weekly. Watering locations were at the lower, west end of all seeded pastures and at the upper, east side of the two native pastures. Salt was provided in troughs near the watering locations. Most seeded pastures had a few juniper trees or brush stacks in variable amounts that provided the sheep some shelter from the sun.

At the Scofield site the ewes were grouped into one herd of some 600 ewes, plus their lambs, under the care of a herder.

Table 1. Species, grazing intensities, pastures, number of ewes, and degree of utilization for experimental area in Tintic Valley near Eureka, Utah, in 1966.

| Species | Grazing intensity | Pasture number | Number of ewes | Percent utilization on selected dates | | |
|---|---|---|---|---|---|---|
| | | | | 5-20 | 6-10 | 7-7 |
| Native | -- | 27 | 56 | - | - | 43 |
| | | 28 | 56 | - | - | 67 |
| Crested wheatgrass | Light* | 1 | 33 | 17 | 29 | 62 |
| | | 17 | 32 | 10 | 21 | 51 |
| | Heavy | 8 | 69 | 13 | 28 | 54 |
| | | 14 | 70 | 22 | 33 | 64 |
| Intermediate wheatgrass | Light | 7 | 42 | 15 | 20 | 46 |
| | | 23 | 34 | 14 | 24 | 28 |
| | Heavy | 6 | 70 | 22 | 32 | 57 |
| | | 20 | 54 | 36 | 48 | 60 |
| Tall wheatgrass | Light | 5 | 36 | 11 | 22 | 49 |
| | | 21 | 57 | 7 | 26 | 44 |
| | Heavy | 11 | 108 | 23 | 30 | 64 |
| | | 24 | 111 | 8 | 26 | 51 |
| Average | Light | - | 39 | 12 | 24 | 47 |
| | Heavy | - | 80 | 21 | 33 | 58 |

* Initial stocking rates were based on a history of forage production and animal performance with intent to obtain 40% and 60% utilization by the end of the grazing period for light and heavy, respectively.

The herder interfered with the sheep only to control the general area they grazed daily. He supplied salt on alternate days, usually near the bedding location. Water was available from small creeks in the bottom of the canyons.

# METHODS AND PROCEDURES

## Pilot Work

A pilot study was conducted at the Scofield mountain site during the summer of 1965 to develop reliable techniques for the principal study. Field work began when the study herd arrived on mountain range from the Eureka foothill site about July 1, and continued into September. All sheep were paint branded by number, and two ewes from each pasture at Eureka were specially marked with bright orange paint on hips, shoulders and back of the neck. Initial plans were to follow and record the activities of a selected, marked individual continuously each day while monitoring environmental conditions.

### Limitations

Due to complications of the herd size and movement, obstruction by vegetation and lying posture, continuous observation of an individual ewe was not possible by a lone observer. Marked ewes selected by random number for observation on a given day often could not be located at the beginning of the day. Frequently an animal that was observed throughout most of the day was lost to view for longer or shorter periods late in the day. Sheep activities were monitored during three, 24-hour days during the summer of 1965. Use of light to identify night activities seemed to disturb the resting herd. Activities recorded at night were almost entirely standing and lying ruminating and idling. Bedded sheep did not appear to sleep. On one occasion after disturbance the sheep grazed a few minutes, while moving to a nearby location. A 24-hour day of observation caused observer fatigue and increased the interval required for rest between observation days.

Method of recording

In the pilot study I made observations on two marked individual ewes once every 10 minutes throughout the day from 0500 to 1950 hours. I recorded the activities of the first two marked ewes visually discovered at the observation instant. This technique constituted a simple scan sampling at instants 10 minutes apart (Altmann 1974). When several marked ewes could be seen simultaneously, the herd was mentally divided, left and right, and the activity of one marked ewe from each side of the herd was recorded. Frequently I was obliged to move to several vantage points to locate two marked ewes at any one observation instant. The study herd was accustomed to seeing people on horseback, and most observations were made while thus mounted. Binoculars were used to determine ewe behavior from distances that were less disruptive. Data on sheep activities were at first recorded on tape and subsequently transferred to data sheets. Later in the study the information was handwritten on small index cards carried in a pocket.

Activities recorded

Activities were tentatively defined based on behavioral literature, but these definitions later were amended from field experience. Feeding, salting, watering, defecating, urinating, nursing and licking lamb, standing ruminating, lying ruminating, standing idle, lying idle, and walking or traveling were initially recorded. Later salting and watering were included in feeding while other minor activities, timewise, such as nursing and licking lamb, urinating, and defecating, were included in their associated activities and postures.

## Environmental variables

Temperature and relative humidity were recorded each hour using a sling psychrometer. Sunset and sunrise times were noted as they occurred at the location of the herd, rather than using official times for these events.

## Pilot study design

Data obtained in the pilot study were statistically analyzed in their original form of number of observations for each activity each day to obtain components of variance for each activity (Table 2). Variances were estimated for the differences due to days, to animals selected at each observation instant, and to experimental error within animals, using the daily totals for observation scans of each activity. Days were considered random model effects. Since different individual ewes were likely chosen at each observation scan, the between-animal variation properly could be assigned to experimental error,

Table 2. Experimental design for the pilot study in 1965 on sheep activities.

| Source of variation | Degrees of freedom | Expected mean squares |
|---|---|---|
| Total | 23 | |
| Days | 11 | $\sigma^2 + 2\sigma_d^2$ |
| Animals | 1 | $\sigma^2 + 12\sigma_a^2$ |
| Error | 11 | $\sigma^2$ |

but was separated here to help locate sources of variation and to check for bias in the animal selection method.

### Interpretation

Number of observations recorded for each activity at the 10-minute intervals during the day were multiplied by 10 and assumed to represent the time spent by sheep daily in each activity (Altmann 1974; Box and Pook 1974; Nelson and Furr 1966; Hull, Lofgreen, and Meyer 1960).

## Principal Study

### Scan sampling

Activities of individual ewes were recorded under typical range sheep grazing situations near Eureka and Scofield, Utah, in 1966. At both locations scan sampling observations were made every 10 minutes (Altmann 1974). The current activity was noted separately for four of the marked ewes in the herd.

Eight ewes per pasture at the Eureka foothill range site were identified with red wool-paint brands at the time sheep were released into each pasture individually. Observations on four of the marked ewes were recorded at the end of each 10-minute interval. On mountain range near Scofield activities were recorded separately on four marked sheep as they could be located by the observer at each observation instant. Marked sheep that had been used earlier on foothill pasture studies numbered about 100 among more than 600 ewes in one flock on the mountain site.

### Activity definitions

Activities recorded were feeding, standing ruminating, lying ruminating, standing idle, lying idle, and traveling (Table 3). These were chosen and defined to be all-inclusive. All less-time-consuming activities such as watering, salting, nursing of lamb, defecating, and urinating were not separated from the six activities of principal interest.

Environmental measurements

Factors recorded. Ambient temperature in degrees Fahrenheit and percentage relative humidity were determined with a sling psychrometer at each hour during animal observation. The observer made these recordings at his vantage point near or within the sheep herd. Wind velocity was estimated hourly using the Beaufort scale (Table 4) as described by Taylor (1954). Degree of cloudiness was recorded hourly on a simple arbitrary 0 to 3 scale with 0 for clear skies, 1 for less than 50% cloud cover, 2 for less than 50% cloudless skies, and 3 for completely overcast skies.

Analyses. The 15 hourly observations of environmental factors were averaged for each observation day and used as independent variables in a multiple regression analysis of daily activity at both the foothill and mountain range sites. The data were analyzed by a stepwize deletion, multiple regression procedure in which the variable producing the least sum of squares for regression was eliminated from the model for the next step. Thus, the procedure evaluated regression models with one to four environmental factors for each of the six sheep activities (Table 5). A dummy variable was included to evaluate the intercepts. Regression coefficients for all tested variables were obtained at each stage of the deletion procedure. Significance of the

Table 3. Definitions of sheep activities recorded in study of sheep behavior on central Utah ranges, 1966.

FEEDING

Grazing, browsing, or any form of animal harvest of forage whether grass, forbs, or browse; eating or licking salt; drinking or muzzle contact with drinkable water; travel occurring while continuously feeding.

RUMINATING

Regurgitation and mastication of boli; swallowing of masticated food; the pause of 0-20 seconds common between swallowing and regurgitation of the next bolus.

Separated into ruminating in standing and lying postures.

IDLING

Resting without ruminating or feeding; minor movement not associated with feeding nor of such duration or extent to be called traveling; pushing against other sheep; stamping feet and other insect avoiding movement not traveling; panting or shivering.

Separated into idling in standing and lying postures.

TRAVELING

Locomotion by sheep from one place to another; moving at least 5 paces if interspersed with movement of feeding; not including movement necessary during feeding.

Table 4. Beaufort scale of wind forces and criteria over land along with average velocity and codes recorded for wind conditions in sheep activity study.

| Code number | Criteria over land | Speed in mph |
|---|---|---|
| 0 | Smoke rises or dust falls vertically | Less than 1 |
| 1 | Smoke or dust drifts with wind; not felt on face | 1 - 3 |
| 2 | Wind felt on face; leaves rustle or quake | 4 - 7 |
| 3 | Leaves and small twigs in constant motion; light cloth flag extends | 8 - 12 |
| 4 | Raises dust and loose paper; moves small branches | 13 - 18 |
| 5 | Sways small trees in leaf | 19 - 24 |
| 6 | Moves large branches; telegraph wires whistle | 25 - 31 |
| 7 | Inconvenience felt in walking against wind | 32 - 38 |

Table 5. Multiple regression analysis of variances model used to evaluate effects of environmental factors on sheep activities.

| SV | df | Model |
|---|---|---|
| Total | 223 | |
| V1 | (1) | |
| V2:V1 | (1) | |
| V3:V1,V2 | (1) | |
| V4:V1,V2,V3 | (1) | |
| Model | 4 | A=B0X0+B1X1+B2X2+B3X3+B4X4+ε |
| Residual | 219 | |
| V4 | (1) | |
| V3:V4 | (1) | |
| V2:V4,V3 | (1) | |
| Model | 3 | A=B0X0+B4X4+B3X3+B2X2+ε |
| Residual | 220 | |
| V4 | (1) | |
| V2:V4 | (1) | |
| Model | 2 | A=B0X0+B4X4+B2X2+ε |
| Residual | 221 | |
| V4 | (1) | |
| Model | 1 | A=B0X0+B4X4+ε |
| Residual | 222 | |

regression based on mean square ratios was tested against four times the appropriate tabular F values (Draper and Smith 1966. p64).

## Experimental design

Mountain site. Studies on mountain range near Scofield were designed and evaluated considering the 28 observation days as treatments with the four animals as samples (Table 6).

Separate analyses were made for each of the six defined and recorded activities. All activity data for both sites were statistically analyzed first in their raw form of number observations recorded for each activity and afterwards translated into minutes per day by multiplying by 10 since scans were made at 10-minute intervals.

Foothill site. Data generated by the studies on foothill range near Eureka were analyzed by two separate designs for each activity (Ostle 1963). Both designs featured two replications based on two separate pastures of each treatment and two months, May and June. Small herds of sheep were assigned to each of the 14 pastures and sheep activities observed and recorded such as to meet the design restrictions simultaneously imposed by both experimental designs (Table 7). Pasture situations or treatments included native foothill range stocked moderately and three species of seeded wheatgrass pastures stocked either light or heavy. Intensity of stocking on the seeded crested, intermediate, and tall wheatgrass pastures was achieved by controlling the number of ewes introduced to each pasture relative to its estimated carrying capacity.

The first model considered the native pastures plus the two intensities of stocking on three species of seeded grasses as seven

Table 6. Model for analysis of components of variance for sheep activities on mountain range, 1966.

| SV | df | EMS |
| --- | --- | --- |
| Total | 111 | |
| Days | 27 | $\sigma^2 + 4\ \sigma_d^2$ |
| Animals | 3 | $\sigma^2 + 28\ \sigma_a^2$ |
| Error | 81 | $\sigma^2$ |

Table 7. Dates of daily observations, pasture numbers, vegetation, and grazing intensities on foothill range at Tintic pastures in May and June, 1966.

| Day | Date | Pasture number | Species | Grazing intensity |
|---|---|---|---|---|
| 1 | 5-3 | 21 | Tall wheatgrass | Light |
| 2 | 5-5 | 27 | Native foothill | - |
| 3 | 5-7 | 24 | Tall wheatgrass | Heavy |
| 4 | 5-11 | 8 | Crested wheatgrass | Heavy |
| 5 | 5-13 | 1 | Crested wheatgrass | Light |
| 6 | 5-15 | 6 | Intermediate wheatgrass | Heavy |
| 7 | 5-17 | 7 | Intermediate wheatgrass | Light |
| 8 | 5-19 | 14 | Crested wheatgrass | Heavy |
| 9 | 5-21 | 5 | Tall wheatgrass | Light |
| 10 | 5-23 | 11 | Tall wheatgrass | Heavy |
| 11 | 5-25 | 28 | Native foothill | - |
| 12 | 5-27 | 23 | Intermediate wheatgrass | Light |
| 13 | 5-29 | 20 | Intermediate wheatgrass | Heavy |
| 14 | 5-31 | 17 | Crested wheatgrass | Light |
| 15 | 6-6 | 28 | Native foothill | - |
| 16 | 6-8 | 11 | Tall wheatgrass | Heavy |
| 17 | 6-10 | 5 | Tall wheatgrass | Light |
| 18 | 6-14 | 17 | Crested wheatgrass | Light |
| 19 | 6-15 | 20 | Intermediate wheatgrass | Heavy |
| 20 | 6-16 | 23 | Intermediate wheatgrass | Light |
| 21 | 6-17 | 14 | Crested wheatgrass | Heavy |
| 22 | 6-19 | 8 | Crested wheatgrass | Heavy |
| 23 | 6-20 | 1 | Crested wheatgrass | Light |
| 24 | 6-22 | 24 | Tall wheatgrass | Heavy |
| 25 | 6-24 | 7 | Intermediate wheatgrass | Light |
| 26 | 6-26 | 27 | Native foothill | - |
| 27 | 6-27 | 21 | Tall wheatgrass | Light |
| 28 | 6-29 | 6 | Intermediate wheatgrass | Heavy |

treatments (Table 8). Selected comparisons investigated included native range pastures versus the seeded pastures and an orthogonal comparison among the seeded pastures.

The second analyses omitted the native range pastures leaving the remaining pastures as a 3 x 2 factorial combination of species and intensities (Table 9).

Scope of study

Activities were recorded from 0500 to 1950 hours USA Mountain Standard Time. Beginning and ending times were chosen to include the active day of the sheep even on the longest days of the year. Each 15 hour observation day featured activities of four ewes separately at 90 observation instants, or 360 activity recordings per day. Since activities of four ewes were recorded throughout the day, each day of study yielded four animal observation days.

At Eureka and also at Scofield, activities were recorded on 28 separate days. Thus 112 animal observation days were recorded at each location for a total of 224 animal observation days for the entire study.

During the principal study in 1966 each actual observation day began at 1200 hours, continued until 1950 hours, then resumed the next morning at 0500 hours to end at noon. This procedure proved sustainable on an alternate day basis for the lone observer for the duration of both the foothill and mountain range work.

Table 8. Fixed effects model for analyses of variances for each of six activities on foothill range as seven treatments with selected comparisons.

| SV | df | EMS |
|---|---|---|
| Total | 111 | |
| Replications | 1 | $\sigma_a^2 + 4\sigma^2 + (56/1)\ \Sigma r^2$ |
| Treatments | 6 | $\sigma_a^2 + 4\sigma^2 + (16/6)\ \Sigma t^2$ |
| Native vs Seeded | (1) | |
| Among Seeded | (5) | |
| Months | 1 | $\sigma_a^2 + 4\sigma^2 + (56/1)\ \Sigma m^2$ |
| T x M | 6 | $\sigma_a^2 + 4\sigma^2 + (8/6)\ \Sigma\Sigma(tm)^2$ |
| Error | 13 | $\sigma_a^2 + 4\sigma^2$ |
| Animals | 84 | $\sigma_a^2$ |

Table 9. Fixed effects model used for factorial analyses of variances for each of six activities on foothill range, 1966.

| SV | df | EMS |
|---|---|---|
| Total | 95 | |
| Replications | 1 | $\sigma_a^2 + 4\sigma^2 + (12/1)\ \Sigma r^2$ |
| Species | 2 | $\sigma_a^2 + 4\sigma^2 + (8/2)\ \Sigma w^2$ |
| Intensity | 1 | $\sigma_a^2 + 4\sigma^2 + (12/1)\ \Sigma u^2$ |
| S x I | 2 | $\sigma_a^2 + 4\sigma^2 + (4/2)\ \Sigma\Sigma(wu)^2$ |
| Month | 1 | $\sigma_a^2 + 4\sigma^2 + (12/1)\ \Sigma m^2$ |
| M x S | 2 | $\sigma_a^2 + 4\sigma^2 + (4/2)\ \Sigma\Sigma(wm)^2$ |
| M x I | 1 | $\sigma_a^2 + 4\sigma^2 + (6/1)\ \Sigma\Sigma(um)^2$ |
| M x I x S | 2 | $\sigma_a^2 + 4\sigma^2 + (2/2)\ \Sigma\Sigma\Sigma(wum)^2$ |
| Error | 11 | $\sigma_a^2 + 4\sigma^2$ |
| Animals | 72 | $\sigma_a^2$ |

# RESULTS

## Pilot Study

### Scope of pilot study

Purpose. A pilot study of domestic sheep activities of central Utah rangelands was begun following preliminary sheep watching in the grazing environment. The initial investigation was conducted at the Scofield site to determine the general behavior of the study herd under Utah rangeland situations and to develop and test for reliable and useful methodology.

Interpretation. Results of the pilot study helped define activities to make them all-inclusive and mutually exclusive, determine limitations, identify environmental factors to monitor, and estimate the numbers of animals and days needed in the principal investigation. As in the later work, data tabulated were the number of observations for each activity each day at instantaneous scans at 10-minute intervals. Data were analyzed in their original form, then numbers were multiplied by 10 and interpreted as minutes per day.

### Temporal patterns

Daily movement. Sheep traveled and fed downhill as a group from overnight bedgrounds on ridges each morning. They spent the midday period in shade at the lower elevations. In the afternoon the herd fed and traveled back uphill to the night's bedding area. This pattern of downhill movement in the morning followed by the afternoon uphill movement occurred every day sheep activities were studied.

Feeding periods. Daily feeding by the sheep was bimodal with both morning and afternoon feeding periods. During the 1965 pilot study sheep on the average began their morning feeding period at 0530 hours, or about 30 minutes prior to local sunrise. The herd usually began feeding as they left the bedgrounds, but at times they walked 100-200 m before feeding. The herd then fed downhill for approximately 210 minutes, or during the next 21 scans (Figure 4). Generally the sheep stopped feeding several hundred meters before reaching the canyon bottoms in which they sought shelter provided by conifer trees. Upon arrival at the repeatedly used resting areas some sheep drank water from small streams. Not all animals drank each day.

On the average the sheep resumed feeding 440 minutes after the cessation of morning feeding and continued for approximately 210 minutes, the same duration as the morning feeding period. Upon reaching the ridge tops the sheep usually consumed supplemental salt provided by the herder. Feeding ended at about 1950 hours, some 40 minutes after observed sunset.

Rumination and idling. Following the morning feeding period and upon reaching available shade, sheep spent most of the midday period from about 0850 to 1610 hours ruminating and idling in either standing or lying postures. The period devoted to ruminating and idling was seldom interrupted by feeding or traveling. Rarely a few sheep would feed momentarily in the immediate vicinity of the resting area. The resting area itself was often devoid of forage. Frequently single ewes would walk to the nearby stream or pond to drink then return directly to shade where they continued to ruminate or idle. Only 31 minutes (7%) of the 440-minute midday period was spent traveling.

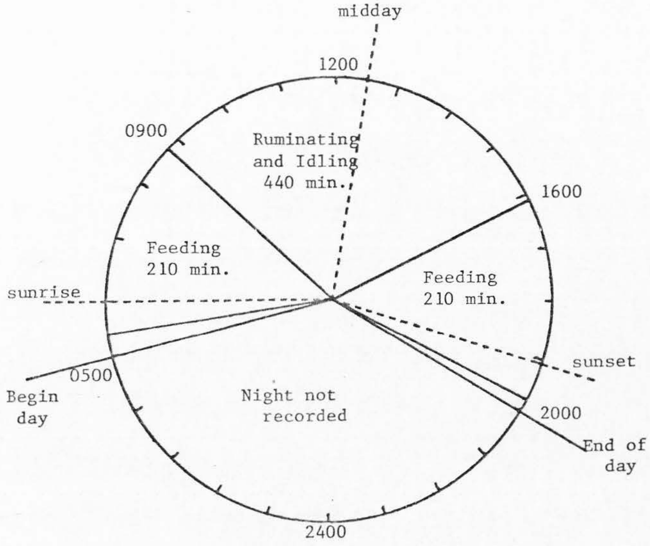


Figure 4. Schematic daily activity pattern of domestic ewes in central Utah during 1965 preliminary study.

Some 87% of all ruminating and idling occurred during the midday period. Nearly all lying idle, 99%, and most lying ruminating, 91%, and standing ruminating, 87%, occurred during the period between feedings. Only 77% of the standing idle occurred during midday, as the sheep often stood idle on the bedgrounds before morning feeding.

Within the midday period 51% of the time was spent ruminating and 42% idling. Portions of the midday period accounted for by these four activities were standing ruminating, 29%; standing idle, 26%; lying ruminating, 22%; and lying idle, 16%.

Panting and shading. During the midday period of ruminating and idling most ewes sought shade for their heads at least. Shade on the mountain range site was generally available for the entire herd in the form of canopy cover by large conifer trees. The sheep often held their heads in the shade created by their neighbor even when tree shade was nearby.

On 10 of the 12 days in 1965 the maximum ambient temperature occurred while the sheep were in shade ruminating or idling. On the other 2 days the maximum temperature was measured after the afternoon feeding had begun. Daily maximum ambient temperature ranged from 14 to 25 C with an average of 21 C. The sheep were observed to pant while otherwise idle on those days (6 of 12) when the ambient temperature exceeded 22 C.

Relation of sunrise and sunset. The sheep began morning feeding shortly before sunrise and ceased afternoon feeding 40 minutes after sunset. The two feeding periods were of equal length. Thus the midday period of rumination and idling was located midway between sunrise and sunset. Ewes were observed never to feed more than 10 minutes prior to 0500 hours nor more than 15 minutes past 1950 hours.

Relation to habitat. The area grazed by the sheep in the 1965 pilot study consisted primarily of short spurs running north and downhill from a common east-west ridge. Sheep were limited mostly to east and west exposures of the smaller ridges plus some small north-facing areas. Feeding occurred in the sagebrush-grass and aspen areas on the east and west slopes while midday rumination and idling occurred in the shade of fir trees on north and east exposures. No evidence was collected that suggested the exposure or vegetation type affected the beginning or ending of any activities.

Relation to rainfall. All incidents of rainfall occurred while the sheep were in shade during the midday period. The ewes sought shelter from the rain by standing beneath fir canopy where they remained standing during the rain. On the one day that rain occurred late in the midday period the sheep did not begin feeding until after the rain stopped, some 40 minutes later than was usual. Feeding then was synchronous and uninterrupted on the wet forage.

Ewe-lamb activities. Lambs suckled frequently during the day, often after a change in activity or posture of the ewe. Most lambs suckled prior to leaving the bedground each morning. Lambs occasionally interfered with ewe feeding in attempting to suckle on the move. Both ewes and lambs frequently called to each other in July but such attention and suckling declined in August and were unnoted in September.

### Flock synchrony

Sheep in the pilot study engaged in the same activity simultaneously more than could be expected if they selected activities independently of other sheep in the flock (Table 10). The two animals selected at each observation scan were recorded as engaged in the same activity more than three times as frequently as could be expected by randome choice of activity. When activities were weighted by their proportion of the daily activity, synchrony was more than twice that expected. In 58% of the scans both sheep being recorded were engaged in the same activity.

Twice the expected feeding activity, 88%, was synchronous. Standing idle and standing ruminating showed similar synchrony to feeding. Both lying activities were more than three times as synchronous as predicted for random simultaneous activity. The travel data indicated that activity was more than six times as synchronous as predicted. All sheep activities appeared to be strongly allelomimetic.

Time budgets for activities

Observations per activity. In 1965 on mountain range the sheep were observed feeding at 39 of the 10-minute interval scans daily on the average. Standing ruminating and lying ruminating accounted for 15 and 10 observations, respectively. At 15 scans the sheep were standing idle. Sheep in the pilot study were found to be lying idle at 7 scans and traveling at 4 scans each day on the average. When multiplied by 10 the number of daily scans yielded an estimate of the amount of time, in minutes per day, the sheep devoted to each activity (Table 11).

Almost half the day was spent foraging or in other mobile behavior. The remainder was spent in less-energy-demanding activities.

Table 10. Degree of synchrony in sheep activities between two "individuals" in a herd in 1965 pilot study, comparing observed data with binomial frequencies weighted by time spent in each activity.

| Activity | Binomial term | Number synchronous | Sightings expected | Sightings observed | Chi-square |
|---|---|---|---|---|---|
| FEEDING p = .430555, q = .569445 | | | | | |
| | .324267 | 0 | 350.21 | 560 | 152.58** |
| | .490355 | 1 | 529.58 | 109 | 337.98** |
| | .185378 | 2 | 200.21 | 411 | 252.90** |
| STANDING RUMINATING p = .165277, q = .834723 | | | | | |
| | .696761 | 0 | 752.50 | 792 | 9.30 |
| | .275922 | 1 | 298.00 | 219 | 26.88** |
| | .027317 | 2 | 29.50 | 69 | 206.12** |
| LYING RUMINATING p = .116666, q = .883334 | | | | | |
| | .780278 | 0 | 842.70 | 876 | 11.00 |
| | .206111 | 1 | 222.60 | 156 | 38.24** |
| | .013611 | 2 | 14.70 | 48 | 199.22** |
| STANDING IDLE p = .161111, q = .838889 | | | | | |
| | .703734 | 0 | 760.03 | 790 | 14.17 |
| | .270309 | 1 | 291.93 | 232 | 32.08** |
| | .025957 | 2 | 28.03 | 58 | 72.78** |
| LYING IDLE p = .080000, q = .920000 | | | | | |
| | .846400 | 0 | 914.11 | 932 | 8.29 |
| | .147200 | 1 | 158.98 | 123 | 36.70** |
| | .006400 | 2 | 6.91 | 25 | 111.43** |
| TRAVELING p = .044444, q = .955556 | | | | | |
| | .913086 | 0 | 986.13 | 998 | 0.96 |
| | .084938 | 1 | 91.73 | 68 | 13.52 |
| | .001975 | 2 | 2.13 | 14 | 142.70** |

** indicates statistical significance at the 99% level for chi-square values in a one-tailed test.

Table 11. Time spent by sheep in specified activities during 15-hour days in 1965 on a central Utah mountain range.

| | Postures | | | | | |
|---|---|---|---|---|---|---|
| | Standing | | Lying | | Total | |
| Activities | minutes | percent | minutes | percent | minutes | percent |
| Feeding | 388 | 43 | | | 388 | 43 |
| Ruminating | 149 | 17 | 105 | 12 | 254 | 29 |
| Idling | 146 | 16 | 72 | 8 | 218 | 24 |
| Traveling | 40 | 4 | — | — | 40 | 4 |
| Totals | 723 | 80 | 177 | 20 | 900 | 100 |

Posture budgets. Only 20% of the day was spent in the lying posture, and less than half the total ruminating time was spent lying down. More than half the standing time was devoted to feeding or traveling. The sheep stood while idling twice as often as they lay while idling (Table 11).

Relation to temperature. Though data were limited, time spent feeding and lying each showed significant simple regressions on average daily temperature (Table 12). Regressions of all other activities or posture combinations on temperature were not significant. In 1965 the sheep spent more time feeding on cooler days in late August and early September. Sheep fed less in early summer when the average daily temperatures were higher. On those days the sheep spent more time in the lying posture, either ruminating or idling.

The range of temperatures observed, 3-25 C, was not great in 1965. Average daily minimum temperature was 9 C, and the average daily maximum was 21 C for a mean daily range of only 12 C. Average daily temperature for the 180 hourly recordings was 15.4 C. The ambient temperature averaged 13 C when the sheep ceased morning feeding and 18 C when afternoon feeding began. The relative humidity at these times averaged 57% and 44%, respectively. Regression of feeding time daily on a temperature-humidity index as used by Ehrenreich and Bjugstad (1966) produced a coefficient of determination of 0.54, similar to the value I found for temperature alone (Table 12).

Evaluation of pilot methodology

Components of variance. The amount of time sheep spent feeding, standing ruminating, standing idle, lying ruminating, and lying idle

Table 12. Separate simple linear regressions of daily activity times on mean ambient temperatures F for 12 days in preliminary study on summer range in central Utah.

| Activity | Regression coefficient ($b_1$) | Coefficient of determination ($r^2$) |
|---|---|---|
| Feeding | -.83 | .53 |
| Standing ruminating | .21 | .06 |
| Lying ruminating | .48 | .28 |
| Standing idle | -.11 | .02 |
| Lying idle | .15 | .04 |
| Traveling | .06 | .08 |
| Total ruminating | .69 | .18 |
| Total idling | .04 | .00 |
| Total standing (idle or ruminating) | .10 | .01 |
| Total lying (idle or ruminating) | .63 | .41 |

varied significantly from day to day (Table 13). Travel time did not vary much from day to day, but differed between animals. These pilot study data indicated that an increase in the number of days of study would produce the greatest improvement in statistical efficiency.

Sensitivity of methods. Only feeding time was sampled within 10% of the mean (Table 14). The data suggested that the number of days that would be needed to sample each activity within 10% of its mean value without changing procedures, ranged from 16 days for feeding to 193 days for lying idle. Minor activities like defecation, were not properly subject to sampling by the methods used.

Herder and observer effects. In the pilot study the herder sometimes forced the sheep to leave the overnight bedground in the morning or the midday resting site in the afternoon sooner than they would have moved of their own choice. The sheep seemed to quickly adapt to the nearby presence of the observer, who remained in view of much of the herd at all times. In some cases the sheep may have awaited the arrival of the herder before initiating afternoon feeding. The herder influenced only the direction the sheep took as they began feeding on mountain range and did not enter the foothill pastures on the day of observation.

## Principal Study

The principal investigation was conducted in 1966 to determine the time budgets of domestic sheep for important activities as influenced by range type, seeded species, stocking pressure, and weather factors to provide inputs for better management.

Table 13. Components of variation for each sheep activity on mountain range in preliminary study, 1965.

| Source | df | SS | MS | EV# | F |
|---|---|---|---|---|---|
| FEEDING | | | | | |
| Total | 23 | 1238.50 | | | |
| Days | 11 | 1203.50 | 109.41 | 53.39 | 41.50** |
| Animals | 1 | 6.00 | 6.00 | .28 | 2.28 |
| Error | 11 | 29.00 | 2.64 | 2.64 | |
| STANDING RUMINATING | | | | | |
| Total | 23 | 748.62 | | | |
| Days | 11 | 612.12 | 55.65 | 22.30 | 5.04** |
| Animals | 1 | 15.04 | 15.04 | .33 | 1.36 |
| Error | 11 | 121.46 | 11.04 | 11.04 | |
| LYING RUMINATING | | | | | |
| Total | 23 | 761.62 | | | |
| Days | 11 | 683.12 | 62.10 | 28.32 | 11.37** |
| Animals | 1 | 18.38 | 18.38 | 1.08 | 3.37 |
| Error | 11 | 60.12 | 5.46 | 5.46 | |
| STANDING IDLE | | | | | |
| Total | 23 | 790.00 | | | |
| Days | 11 | 704.00 | 64.00 | 28.21 | 8.44** |
| Animals | 1 | 2.67 | 2.67 | .00 | .35 |
| Error | 11 | 83.33 | 7.58 | 7.58 | |
| LYING IDLE | | | | | |
| Total | 23 | 598.50 | | | |
| Days | 11 | 460.50 | 41.86 | 14.04 | 3.04* |
| Animals | 1 | 13.50 | 13.50 | .00 | .98 |
| Error | 11 | 151.50 | 13.77 | 13.77 | |
| TRAVELING | | | | | |
| Total | 23 | 96.00 | | | |
| Days | 11 | 37.00 | 3.36 | .09 | 1.06 |
| Animals | 1 | 24.00 | 24.00 | 1.74 | 7.55* |
| Error | 11 | 35.00 | 3.18 | 3.18 | |

# EV indicates estimated variance due to each source
** denotes significance at the 99% confidence level
* denotes significance at the 95% confidence level

Table 14. Minutes per day spent by sheep in various activities with 95% confidence interval and estimate of number of animal observation days needed to test within 10% of mean.

| Activity | Mean ±95% C.I. | Number needed |
|---|---|---|
| Feeding | 388 ±31 | 16 |
| Standing ruminating | 149 ±24 | 59 |
| Lying ruminating | 105 ±25 | 123 |
| Standing idle | 146 ±24 | 62 |
| Lying idle | 72 ±22 | 193 |
| Traveling | 40 ± 9 | 103 |

Daily pattern of activity

General pattern. Sheep grazing mountain range near Scofield, Utah, from July to September, 1966, exhibited a bimodal pattern of daily activity (Figure 5). Morning and afternoon feeding periods were separated by midday periods of ruminating and idling. Each morning the sheep fed downhill from the previous overnight bedground at higher elevations. The midday resting sites were located along intermittent streams in the canyon bottoms. Each afternoon the sheep moved back uphill while feeding and reached the ridge crest in time for overnight bedding. Ridge sides grazed varied from 20% to 80% slope and the ridges averaged 10% slope. The sheep stayed together loosely as a single flock or herd of some 600 ewes plus their lambs.

Sheep on foothill range at Tintic followed a pattern of morning and afternoon grazing (Figure 6), as was the case on mountain range. The midday period of ruminating and idling was very much shorter on foothill range, and the sheep resumed feeding earlier in the afternoon than on the mountain range situation. The entire flock in each pasture, numbering from 30 to 110 ewes plus lambs, moved as a unit. Even though the pastures only differed by an average of 22 m elevation from the low to the high side, the sheep bedded overnight repeatedly in the highest area of each pasture. In the seeded pastures the sheep fed downhill each morning and then uphill in the afternoon.

Relation to sunrise and sunset. At both locations the sheep usually began morning feeding shortly before sunrise averaging 6 minutes prior to sunrise on mountain range and 23 minutes prior to sunrise on foothill range. The sheep stopped feeding in the evenings after sunset. On the average sheep ceased to feed 10 minutes past

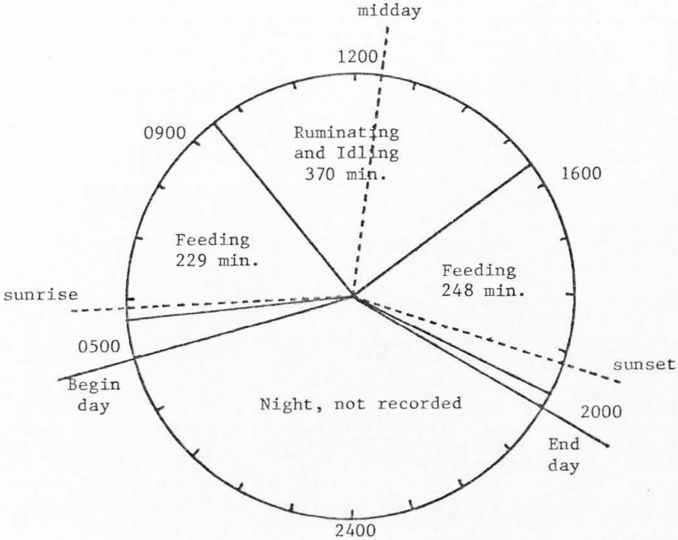


Figure 5. Schematic daily activity pattern of sheep on mountain range in central Utah, summer of 1966.

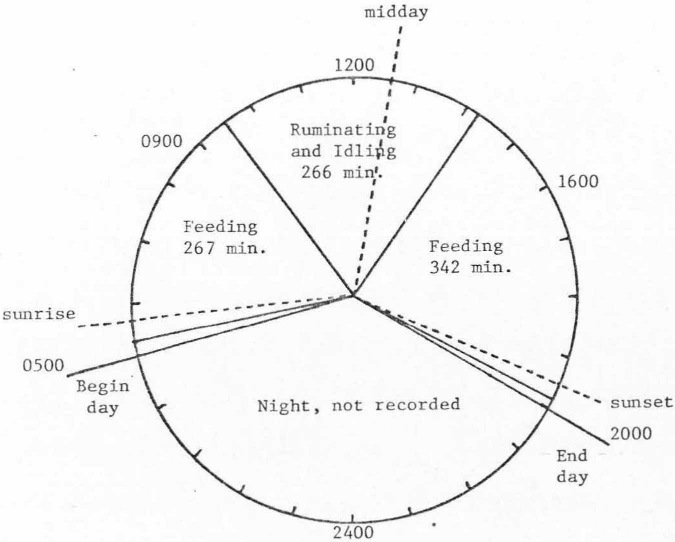


Figure 6. Schematic daily activity pattern of sheep on foothill range in central Utah, spring 1966.

sunset on foothill pastures and 30 minutes past sunset on mountain range. Thus a total of only about 35 minutes of feeding occurred beyond the sunlit hours.

Distance traveled. The average distances traveled by the flock were similar at the two locations averaging 2100 m horizontally (Table 15). Daily travel ranged from 1600 to 3200 m on foothills and 1220 to 3290 m on mountain range.

Vertical travel at the two sites varied by a factor of 10 with the sheep averaging nearly 250 m one-way climb on mountain range but only 22 m on foothills. The afternoon uphill climb ranged from 150 to 300 m on mountain range and 15 to 27 m at Tintic.

On the steep slopes of mountain range the herd selected an average line of travel of 23% slope for feeding and traveling from overnight bedground to midday resting area each direction daily. The herd traveled across the gentle topography of the foothill pastures at a 2% slope.

Individually, the ewes frequently changed directions of travel while feeding and chose a less direct path across the slopes than the herd average movement. Such meandering about increased the distances traveled by individual sheep and also reduced the gradient of vertical travel.

Feeding periods. Feeding periods for both morning and afternoon were longer on foothill range than on mountain range. The morning feeding was of longer duration due to earlier initiation of feeding on foothill range. Likewise, afternoon feeding began earlier on foothill range, resulting in a longer afternoon feeding period. Initiation of afternoon feeding on foothill range was ill-defined, or lacked

Table 15. Mean horizontal and vertical distances traveled by sheep on mountain and foothill ranges, with 95% confidence intervals.

| Site | Components | Distance |
|---|---|---|
| Mountain | Daily horizontal travel | 2127 m ± 218 m |
| | Daily one-way vertical travel | 248 m ± 15 m |
| Foothill | Daily horizontal travel | 2077 m ± 119 m |
| | Daily one-way vertical travel | 22 m ± 2 m |

synchrony, with a few sheep at a time feeding first. On mountain range the sheep began afternoon feeding later than on the foothill location and more as a flock activity.

Midday rumination and idling. On foothill pastures the sheep ruminated and idled during midday for about the same amount of time as they had fed during the morning. On mountain range they spent more time runinating and idling during the midday period than they did on the foothill location.

Bedgrounds. On foothill range the small herd in each pasture usually bedded at the same site at the upper end of the pasture each night; on mountain range the sheep seldom used the same night bedding site more than twice. Successive bedgrounds were usually farther uphill along a ridge crest adjacent to the successive feeding areas. Midday resting areas for ruminating and idling on mountain range were often used for several successive days until the feeding area became so far removed from the resting area that a new closer site was selected following morning feeding. Midday resting areas on the foothill pastures were poorly defined, perhaps due in part to lack of shade, but they were usually located in proximity to the water troughs.

Watering and salting. On the foothill pastures the sheep reached the water troughs during morning feeding, or they ceased feeding and traveled to water after which they resumed feeding. Most sheep drank again in the afternoon as feeding time approached. Supplemental salt, available in troughs near water, was also consumed daily by most sheep while on foothill pastures. On mountain range the sheep consumed salt on alternate days at the end of afternoon feeding just prior to bedding.

Ewe and lamb activities. Ewes began lambing soon after entering the foothill pastures about May 1. Most lambed within the first three weeks of May. The ewes often lambed during the first two hours of morning activity prior to watering. Some ewes followed the feeding herd to water soon after parturition leaving the newborn lamb alone but returned to their lambs soon after watering. More often the ewes stayed behind with their newborn lamb as the herd fed toward water, and both ewe and lamb joined the herd later in the morning. Lambs suckled often during the day. Lambs continued to suckle through most of July on mountain range, but most were weaned naturally by early August. Ewes and lambs both called to one another when separated, but such bleatings declined after weaning.

Synchrony of activity

Since 0 to 4 sheep could be engaged in a given activity at each scan the data were tested for fit to a binomial distribution with five terms to measure the degree of synchrony in sheep activities. Binomial distributions for each activity at each location were based on the proportion of day devoted to an activity. Finally the number of scans at which each possible number of animals was observed was compared to the number that might be expected if sheep timed their activities independently and at random through the day.

Sheep engaged in the same activity simultaneously more often than predicted (Table 16). All four animals were synchronous more often than expected, and there were fewer scans than expected with none of the four animals engaged in a particular activity. Also there were fewer scans than expected in which only one of the four had selected a

Table 16. Degree of synchrony in activities among four sheep in a herd, comparing observed behavior with binomial frequencies based on time spent in each sheep activity.

| Activity | Binomial term | Number synchronous | Sightings expected | Sightings observed | Chi-square |
|---|---|---|---|---|---|
| | | MOUNTAIN SITE 1966 | | | |
| FEEDING | p = .5444, | q = .4556 | | | |
| | .043069 | 0 | 108.53 | 1048 | 8383.08** |
| | .205890 | 1 | 518.84 | 68 | 397.33** |
| | .369097 | 2 | 930.12 | 73 | 792.63** |
| | .294097 | 3 | 741.07 | 65 | 620.02** |
| | .087865 | 4 | 222.42 | 1266 | 4999.97** |
| STANDING RUMINATING | | p = .2278, | q = .7722 | | |
| | .355606 | 0 | 896.13 | 1603 | 597.64** |
| | .419564 | 1 | 1057.30 | 174 | 750.27** |
| | .185634 | 2 | 467.80 | 311 | 86.44** |
| | .036465 | 3 | 91.89 | 274 | 523.75** |
| | .002692 | 4 | 6.78# | 158 | 1398.00** |
| LYING RUMINATING | | p = .1322, | q = .8678 | | |
| | .567067 | 0 | 1429.01 | 1844 | 60.33** |
| | .345613 | 1 | 870.94 | 279 | 417.49** |
| | .078991 | 2 | 199.06 | 210 | 44.87* |
| | .008024 | 3 | 20.22 | 122 | 695.00** |
| | .000306 | 4 | .77 | 65 | 255.00** |
| STANDING IDLE | p = .0444, | q = .9556 | | | |
| | .833727 | 0 | 2100.99 | 2225 | 23.21 |
| | .155112 | 1 | 390.88 | 194 | 140.29** |
| | .010822 | 2 | 27.27 | 78 | 270.00** |
| | .000336 | 3 | .85 | 18 | 32.00 |
| | .000004 | 4 | .01 | 5 | 27.00 |
| LYING IDLE | p = .0122, | q = .9878 | | | |
| | .952000 | 0 | 2399.04 | 2416 | 4.12 |
| | .047118 | 1 | 188.74 | 78 | 48.74** |
| | .000874 | 2 | 2.20 | 19 | 55.00** |
| | .000007 | 3 | .02 | 7 | 31.00 |
| | .00000002 | 4 | .00006 | 0 | 28.00 |

Table 16 continued

| | | | | |
|---|---|---|---|---|
| TRAVELING p = .0389, q = .9611 | | | | |
| .853286 | 0 | 2150.28 | 2338 | 21.66 |
| .138104 | 1 | 348.02 | 66 | 232.74** |
| .008382 | 2 | 21.12 | 54 | 81.00** |
| .000226 | 3 | .57 | 31 | 39.00 |
| .000002 | 4 | .01 | 31 | 111.00** |
| FOOTHILL SITE 1966 | | | | |
| FEEDING p = .6889, q = .3111 | | | | |
| .009368 | 0 | 23.61 | 449 | 9959.00** |
| .082969 | 1 | 209.08 | 205 | 75.84** |
| .275590 | 2 | 694.49 | 235 | 323.97** |
| .406845 | 3 | 1025.25 | 297 | 547.11** |
| .225221 | 4 | 567.54 | 1334 | 1128.09** |
| STANDING RUMINATING p = .2200, q = .7800 | | | | |
| .370151 | 0 | 932.78 | 1518 | 402.78** |
| .417661 | 1 | 1052.37 | 307 | 544.16** |
| .176679 | 2 | 445.23 | 307 | 68.40** |
| .033222 | 3 | 83.72 | 269 | 598.89** |
| .002342 | 4 | 5.90 | 119 | 627.00** |
| LYING RUMINATING p = .0589, q = .9411 | | | | |
| .784447 | 0 | 1976.81 | 2155 | 56.22** |
| .196343 | 1 | 494.78 | 208 | 210.87** |
| .018435 | 2 | 46.46 | 96 | 327.97** |
| .000769 | 3 | 1.94 | 51 | 249.00** |
| .000012 | 4 | .03 | 10 | 60.00** |
| STANDING IDLE p = .0111, q = .9889 | | | | |
| .956291 | 0 | 2409,85 | 2405 | 8.44 |
| .042979 | 1 | 108.31 | 100 | 131.11** |
| .000724 | 2 | 1.83 | 14 | 37.00 |
| .000005 | 3 | .01 | 1 | 27.00 |
| .000000015 | 4 | .00004 | 0 | 28.00 |
| LYING IDLE p = .0033, q = .9967 | | | | |
| .986733 | 0 | 2486.57 | 2492 | 1.33 |
| .013069 | 1 | 32.93 | 27 | 84.99** |
| .000066 | 2 | .17 | 1 | 27.00 |
| .0000001 | 3 | .0003 | 0 | 28.00 |
| .0000000001 | 4 | .0000003 | 0 | 28.00 |

Table 16 continued

TRAVELING p = .0178, q = .9822

| | | | | |
|---|---|---|---|---|
| .930763 | 0 | 2345.52 | 2373 | 5.24 |
| .067465 | 1 | 170.01 | 118 | 62.44** |
| .001834 | 2 | 4.62 | 21 | 35.00 |
| .000022 | 3 | .06 | 7 | 23.00 |
| .0000001 | 4 | .0003 | 1 | 27.00 |

* and ** indicate statistical significance at the 95% and 99% levels for chi-square values in a one-tailed test.

# Expected values less than 28, or 1 per day, were treated as 1 per day in calculating these chi-square values based on data for 28 days at each site.

certain activity. Departures from expected values for two and three animals acting synchronously varied with the proportion of total time spent in each of the activities. Generally all sheep fed at the same time or engaged in some other activity. There were fewer scans with one, two, or three sheep feeding compared with none or all four sheep.

Sheep activities on mountain range

Sheep activities were recorded on mountain range near Scofield, Utah, on 28 of the 57 days from July 12 to September 6 with half the recordings made before and half after August 15 (Table 17). The number of scans recorded for each activity was variable, but some seasonal trends were apparent. Feeding time tended to decrease late in the summer, and was replaced by an increase in time spent standing ruminating. Other activities showed only slight seasonal changes.

Analysis of the field data showed that variation among the four animals was a small component of total variation for each of the six activities (Table 18). Most variation was due to differences among daily means which were highly significant for each activity.

After examination the field data were grouped in periods of 7 days each, and the periods were compared using a Duncan multiple range test (Table 19). Feeding and lying took more of the sheep's time during the first half of the summer than in the latter half, while traveling and standing means were higher during the latter half of the summer.

Feeding was the predominant activity of the sheep while on mountain range, averaging 490 minutes per day. Extremes among animals for the location ranged from 380 to 600 minutes of feeding daily. No fewer than 46 scans as a daily average for the four animals were recorded as

Table 17. Mean minutes spent in each of six activities by sheep on mountain range in central Utah, 1966.

| | | Activities | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Ruminating | | Idling | | |
| Date | Day | Feeding | Standing | Lying | Standing | Lying | Traveling |
| Period 1 | | | | | | | |
| 7-12 | 1 | 520 | 165 | 140 | 72 | 2 | 0 |
| -14 | 2 | 488 | 155 | 255 | 28 | 2 | 0 |
| -19 | 3 | 565 | 148 | 172 | 2 | 0 | 12 |
| -20 | 4 | 592 | 158 | 92 | 12 | 28 | 18 |
| -27 | 5 | 510 | 262 | 95 | 8 | 10 | 15 |
| -29 | 6 | 475 | 228 | 128 | 15 | 30 | 25 |
| -30 | 7 | 488 | 112 | 135 | 18 | 58 | 90 |
| Period 2 | | | | | | | |
| 8- 7 | 8 | 462 | 132 | 155 | 15 | 22 | 112 |
| - 8 | 9 | 572 | 130 | 140 | 12 | 40 | 5 |
| - 9 | 10 | 528 | 90 | 195 | 28 | 8 | 52 |
| -10 | 11 | 575 | 152 | 122 | 25 | 10 | 15 |
| -12 | 12 | 468 | 228 | 115 | 68 | 5 | 18 |
| -13 | 13 | 548 | 155 | 118 | 50 | 8 | 22 |
| -14 | 14 | 522 | 240 | 88 | 35 | 5 | 10 |
| Period 3 | | | | | | | |
| 8-22 | 15 | 502 | 195 | 78 | 80 | 0 | 45 |
| -25 | 16 | 405 | 222 | 140 | 82 | 2 | 48 |
| -26 | 17 | 555 | 180 | 118 | 20 | 0 | 28 |
| -27 | 18 | 425 | 280 | 105 | 52 | 2 | 35 |
| -28 | 19 | 520 | 265 | 65 | 38 | 0 | 12 |
| -29 | 20 | 458 | 258 | 105 | 45 | 0 | 35 |
| -30 | 21 | 400 | 362 | 70 | 20 | 5 | 42 |
| Period 4 | | | | | | | |
| 8-31 | 22 | 460 | 278 | 78 | 40 | 28 | 18 |
| 9- 1 | 23 | 460 | 238 | 80 | 72 | 10 | 40 |
| - 2 | 24 | 445 | 290 | 42 | 82 | 5 | 35 |
| - 3 | 25 | 428 | 190 | 155 | 45 | 12 | 70 |
| - 4 | 26 | 418 | 218 | 168 | 15 | 5 | 78 |
| - 5 | 27 | 470 | 205 | 92 | 72 | 8 | 52 |
| - 6 | 28 | 478 | 195 | 112 | 60 | 8 | 48 |
| Average | | 490 | 205 | 119 | 40 | 11 | 35 |

Table 18. Analysis for components of variation for sheep activities on mountain range based on number of observations recorded for each activity, 1966.

| Sources of variation | df | Sum of squares | Mean squares | F ratios | Estimated variances |
|---|---|---|---|---|---|
| FEEDING | | | | | |
| Total | 111 | 3457.68 | 31.15 | | |
| Days | 27 | 3126.18 | 115.78 | 29.25 ** | 27.96 |
| Animals | 3 | 10.89 | 3.63 | .92 | .00 |
| Error | 81 | 320.61 | 3.96 | | 3.96 |
| STANDING RUMINATING | | | | | |
| Total | 111 | 6903.86 | 62.20 | | |
| Days | 27 | 4198.36 | 155.49 | 5.29 ** | 31.52 |
| Animals | 3 | 324.86 | 108.29 | 3.68 | 2.82 |
| Error | 81 | 2380.64 | 29.39 | | 29.39 |
| LYING RUMINATING | | | | | |
| Total | 111 | 3737.49 | 33.67 | | |
| Days | 27 | 1841.74 | 68.21 | 3.04 ** | 11.44 |
| Animals | 3 | 79.10 | 26.37 | 1.18 | .14 |
| Error | 81 | 1816.65 | 22.43 | | 22.43 |
| STANDING IDLE | | | | | |
| Total | 111 | 1140.92 | 10.28 | | |
| Days | 27 | 702.67 | 26.02 | 5.55 ** | 5.33 |
| Animals | 3 | 58.38 | 19.46 | 4.15 ** | .53 |
| Error | 81 | 379.87 | 4.69 | | 4.69 |
| LYING IDLE | | | | | |
| Total | 111 | 425.49 | 3.83 | | |
| Days | 27 | 206.74 | 7.66 | 3.09 ** | 1.30 |
| Animals | 3 | 15.95 | 5.32 | 2.15 | .10 |
| Error | 81 | 200.47 | 2.47 | | 2.47 |
| TRAVELING | | | | | |
| Total | 111 | 938.00 | 8.45 | | |
| Days | 27 | 807.50 | 29.91 | 18.84 ** | 7.08 |
| Animals | 3 | 1.93 | .64 | .40 | .00 |
| Error | 81 | 128.57 | 1.59 | | 1.59 |

** Indicates significance at the 99% level.

Table 19. Comparison of time spent in specified activities during 7-day periods on mountain range.

| Activity | Periods and period means* | | | |
|---|---|---|---|---|
| FEEDING | (4)# | (3) | (1) | (2) |
| | 451 | 467 | 520 | 525 |
| RUMINATING | | | | |
| STANDING | (2) | (1) | (4) | (3) |
| | 161 | 175 | 230 | 252 |
| LYING | (3) | (4) | (2) | (1) |
| | 97 | 104 | 133 | 141 |
| IDLE | | | | |
| STANDING | (1) | (2) | (3) | (4) |
| | 22 | 33 | 48 | 55 |
| LYING | (3) | (4) | (2) | (1) |
| | 1 | 11 | 14 | 19 |
| TRAVELING | (1) | (2) | (3) | (4) |
| | 23 | 34 | 35 | 49 |

* Means underscored by the same line are not different at the 5% level in Duncan multiple range test.

# Numbers in parentheses refer to periods during the summer, numbers not in parentheses are mean minutes per day.

feeding during the first half of the summer on mountain range when the sheep fed 520 minutes per day. In contrast, sheep fed only 450 minutes per day during the final 7 days, or fourth period.

The sheep stood ruminating 170 minutes per day as an average and did not exceed 280 minutes during the day in the first half of the summer. Later in the season the sheep stood ruminating each day an average of 240 minutes. The increase in standing ruminating late in the season on mountain range equalled the decrease in feeding activity toward the end of the summer.

The sheep spent 2 hours daily ruminating while lying. Only 2 days were encountered when the sheep spent more than 3 hours, 18 scans, lying ruminating on mountain range, both during the first half of the summer. In one of the cases, on Day 10 when the herd fed on Trail Ridge, the sheep remained lying ruminating in fir-tree shade much later than usual before beginning afternoon feeding. On only 7 days late in the summer did sheep spend less than an hour and a half lying ruminating.

Standing idle occupied less time of the sheep on mountain range than feeding or ruminating. Never did the sheep spend as much as 90 minutes standing idle. Except for the first day of study the sheep tended to spend more time standing idle in late summer than earlier.

The study herd spent very little time lying idle on the mountain range situation. Each day sheep spent less than one hour lying idle. On 75% of the days the sheep were found lying idle no more than 10 minutes per sheep per day, and on half the days on mountain range no more than 5 minutes as an average were devoted to lying idle.

From the fourth to the ninth day the sheep averaged about 30 minutes per day lying idle, but at all other times this activity occupied less than 6 minutes per day.

The estimate of traveling time per day for the sheep varied from none to nearly 2 hours on mountain range and averaged 35 minutes per sheep per day at this location. On only 4 days did the estimate exceed 1 hour. Omitting these 4 days of maximum travel still left an average of more than 26 minutes of travel each day. Most daily travel without feeding occurred either just before or just after a period of feeding activity on the mountain range site.

### Sheep activities on foothill range

Time budgets. On 28 of the 58 days from May 3 to June 29, 1966, the activities of sheep were recorded at 90 daily scans at 10-minute intervals between 0500 and 1950 hours. Observations were made in 14 pastures in May and again in June. The number of scans recorded for each of six activities varied by day and treatment, but no seasonal trends were apparent.

On the average the sheep fed 620 minutes daily at the Tintic location (Table 20). Daily feeding estimates ranged from less than 7 hours in a native foothill range pasture to more than 13 hours on a crested wheatgrass pasture.

Estimates of standing ruminating time varied from only 80 minutes to nearly 5 hours on similar pasture. On the average on foothill range the experimental sheep were standing ruminating at about 20 scans daily.

Table 20. Mean minutes spent in each of six activities by sheep on foothill range in central Utah, 1966.

| | | Activities | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Ruminating | | Idling | | |
| Date | Day | Feeding | Standing | Lying | Standing | Lying | Traveling |
| 5- 3 | 1 | 558 | 225 | 42 | 32 | 2 | 40 |
| - 5 | 2 | 412 | 185 | 195 | 70 | 20 | 18 |
| - 7 | 3 | 512 | 260 | 65 | 28 | 5 | 30 |
| -11 | 4 | 650 | 140 | 48 | 18 | 0 | 45 |
| -13 | 5 | 660 | 192 | 22 | 5 | 0 | 20 |
| -15 | 6 | 722 | 110 | 10 | 15 | 0 | 42 |
| -17 | 7 | 702 | 162 | 5 | 12 | 0 | 18 |
| -19 | 8 | 650 | 228 | 8 | 2 | 2 | 10 |
| -21 | 9 | 645 | 195 | 48 | 5 | 0 | 5 |
| -23 | 10 | 620 | 190 | 80 | 0 | 0 | 10 |
| -25 | 11 | 528 | 232 | 62 | 32 | 15 | 30 |
| -27 | 12 | 678 | 200 | 12 | 5 | 0 | 5 |
| -29 | 13 | 730 | 155 | 8 | 0 | 0 | 8 |
| -31 | 14 | 605 | 250 | 10 | 5 | 0 | 30 |
| 6- 6 | 15 | 538 | 190 | 140 | 5 | 2 | 25 |
| - 8 | 16 | 648 | 162 | 85 | 2 | 2 | 0 |
| -10 | 17 | 505 | 218 | 152 | 5 | 10 | 10 |
| -14 | 18 | 590 | 278 | 15 | 2 | 0 | 15 |
| -15 | 19 | 650 | 165 | 75 | 5 | 0 | 5 |
| -16 | 20 | 618 | 268 | 8 | 2 | 0 | 5 |
| -17 | 21 | 655 | 220 | 20 | 0 | 0 | 5 |
| -19 | 22 | 700 | 152 | 15 | 5 | 0 | 28 |
| -20 | 23 | 790 | 80 | 10 | 0 | 0 | 20 |
| -22 | 24 | 660 | 188 | 48 | 0 | 0 | 5 |
| -24 | 25 | 690 | 160 | 32 | 0 | 0 | 18 |
| -26 | 26 | 435 | 255 | 168 | 15 | 15 | 12 |
| -27 | 27 | 612 | 248 | 35 | 0 | 0 | 5 |
| -29 | 28 | 592 | 230 | 78 | 0 | 0 | 0 |
| Average | | 620 | 198 | 53 | 10 | 3 | 16 |

Slightly more than 20% of the estimated ruminating time was spent lying. Estimates for lying ruminating varied from less than 1 scan per animal per day to nearly 20 scans per animal. Greatest total rumination time, including both standing and lying postures, was estimated as more than 7 hours on a native range pasture. In contrast, the sheep ruminated for as little as an hour and a half the day of maximum feeding.

Idling was a minor activity on foothill range with only 13 minutes per day devoted to both standing and lying idle. On 8 days no idling was recorded at any of the 90 scans.

Travel occurred primarily as the sheep interrupted feeding and moved directly to water most mornings. On the average the sheep traveled 16 minutes per day on the foothill location.

Analyses of variance. Analysis of variance was calculated for each activity to determine significance of mean squares for months and treatments. The 7 treatments included the native foothill range treatment plus the 6 combinations of seeded species and intensities of stocking.

Treatment mean squares were significant for all activities except standing ruminating and traveling (Table 21). Most of the variations due to treatments were caused by the differences between native range and seeded pastures. Comparison of native and seeded treatments produced significant variances for feeding, lying ruminating, standing idle, and lying idle.

Months significantly affected only standing idle and traveling.

Table 21. Analyses of variance for six activities of sheep on foothill range at Tintic in 1966 with species and intensity combinations plus native pastures considered as seven treatments.

| ACTIVITY Source of variation | df | Sum of squares | Mean squares | F ratios |
|---|---|---|---|---|
| FEEDING | | | | |
| Total | 111 | 9667.96 | | |
| Replications | 1 | 2.29 | 2.29 | |
| Treatments | 6 | 4963.84 | 827.31 | 4.94 ** |
| Native vs seeded | (1) | 3747.87 | 3747.87 | 22.38 ** |
| Among seeded | (5) | 1215.97 | 243.19 | 1.45 |
| Months | 1 | .14 | .14 | .00 |
| T x M | 6 | 1044.98 | 174.16 | 1.04 |
| Error | 13 | 2176.71 | 167.44 | |
| Sampling | 84 | 1480.00 | 17.62 | |
| STANDING RUMINATING | | | | |
| Total | 111 | 4451.42 | | |
| Replications | 1 | 187.72 | 187.72 | |
| Treatments | 6 | 338.73 | 56.46 | .47 |
| Native vs seeded | (1) | 59.52 | 59.52 | .50 |
| Among seeded | (5) | 279.21 | 55.84 | .46 |
| Months | 1 | 10.94 | 10.94 | .09 |
| T x M | 6 | 400.62 | 66.77 | .55 |
| Error | 13 | 1563.15 | 120.24 | |
| Sampling | 84 | 1950.25 | 23.22 | |
| LYING RUMINATING | | | | |
| Total | 111 | 3851.11 | | |
| Replications | 1 | 3.57 | 3.57 | |
| Treatments | 6 | 1975.61 | 329.27 | 5.93 ** |
| Native vs seeded | (1) | 1440.86 | 1440.86 | 25.95 ** |
| Among seeded | (5) | 534.75 | 106.95 | 1.93 |
| Months | 1 | 100.32 | 100.32 | 1.81 |
| T x M | 6 | 213.18 | 35.53 | .64 |
| Error | 13 | 721.93 | 55.53 | |
| Sampling | 84 | 836.50 | 9.96 | |

Table 21 continued

| ACTIVITY<br>Source of variation | df | Sum of squares | Mean squares | F ratios |
|---|---|---|---|---|
| STANDING IDLE | | | | |
| Total | 111 | 366.92 | | |
| Replications | 1 | 23.22 | 23.22 | |
| Treatments | 6 | 86.86 | 14.48 | 3.83 * |
| Native vs seeded | (1) | 81.48 | 81.48 | 21.55 ** |
| Among seeded | (5) | 5.38 | 1.08 | .29 |
| Months | 1 | 50.22 | 50.22 | 13.29 ** |
| T x M | 6 | 40.71 | 6.79 | 1.80 |
| Error | 13 | 49.15 | 3.78 | |
| Sampling | 84 | 116.75 | 1.39 | |
| LYING IDLE | | | | |
| Total | 111 | 67.96 | | |
| Replications | 1 | .14 | .14 | |
| Treatments | 6 | 21.71 | 3.62 | 7.40 ** |
| Native vs seeded | (1) | 20.37 | 20.37 | 41.66 ** |
| Among seeded | (5) | 1.34 | .27 | .55 |
| Months | 1 | .32 | .32 | .66 |
| T x M | 6 | 3.43 | .57 | 1.19 |
| Error | 13 | 6.36 | .49 | |
| Sampling | 84 | 36.00 | .43 | |
| TRAVELING | | | | |
| Total | 111 | 303.42 | | |
| Replications | 1 | 27.01 | 27.01 | |
| Treatments | 6 | 22.23 | 3.71 | .59 |
| Native vs seeded | (1) | 4.18 | 4.18 | .67 |
| Among seeded | (5) | 18.05 | 3.61 | .58 |
| Months | 1 | 35.44 | 35.44 | 5.68 * |
| T x M | 6 | 14.38 | 2.40 | .38 |
| Error | 13 | 81.12 | 6.24 | |
| Sampling | 84 | 123.25 | 1.47 | |

* and ** indicate significance at the 95% and 99% levels of confidence, respectively.

In separate analyses of variance, data for the native foothill range were omitted so that data for the seeded pastures could be analyzed separately as a factorial combination of 3 species of forage and 2 intensities of stocking to increase precision. In these analyses neither intensity of stocking nor any of the interactions produced significant mean squares (Table 22). Species mean square was significant for the lying ruminating activity. Months provided a significant source of variation in data for standing idle and traveling time for sheep on seeded foothill pastures. Species mean square for feeding time was significant only at the 90% level. The error mean squares derived in the factorial analyses of variance were also utilized to test the mean squares due to variation among the seeded pasture treatments in the previous 7 treatment analysis. They provided a more precise error term for these selected comparisons which did not include the native pasture treatment. By this method all but one of the activity tests remained unchanged. For lying ruminating data the Among seeded treatment comparison F-test value was 3.47, a significant value at the 95% confidence level.

Treatment effects. On the foothill location the sheep fed less time daily on the native range pastures than they did on pastures seeded to introduced wheatgrasses (Table 23). During that period the sheep spent more time lying ruminating and standing and lying idle on the native pastures. No differences in any of the activities of the sheep could be ascribed to intensity of stocking.

Though analysis of variance tests for difference due to seeded species of wheatgrass were highly significant for lying ruminating, the three species means were not different from each other by the

Table 22. Factorial analysis of variance of sheep activities on seeded foothill range pastures at Tintic in 1966.

| ACTIVITY<br>Source of variation | df | Sum of squares | Mean squares | F ratios |
|---|---|---|---|---|
| FEEDING | | | | |
| Total | 95 | 5373.66 | | |
| Replications | 1 | 110.51 | 110.51 | |
| Species | 2 | 1143.19 | 571.59 | 3.94 |
| Intensity | 1 | 31.51 | 31.51 | .22 |
| S x I | 2 | 41.27 | 20.64 | .14 |
| Months | 1 | .84 | .84 | .01 |
| M x S | 2 | 583.19 | 291.59 | 2.01 |
| M x I | 1 | 6.51 | 6.51 | .04 |
| M x I x S | 2 | 444.02 | 222.01 | 1.53 |
| Error | 11 | 1593.86 | 144.90 | |
| Sampling | 72 | 1418.75 | 19.70 | |
| STANDING RUMINATING | | | | |
| Total | 95 | 4011.96 | | |
| Replications | 1 | 240.67 | 240.67 | |
| Species | 2 | 140.58 | 70.29 | .56 |
| Intensity | 1 | 126.04 | 126.04 | 1.00 |
| S x I | 2 | 12.58 | 6.29 | .05 |
| Months | 1 | 6.00 | 6.00 | .05 |
| M x S | 2 | 231.25 | 115.62 | .92 |
| M x I | 1 | .17 | .17 | .00 |
| M x I x S | 2 | 166.58 | 83.29 | .66 |
| Error | 11 | 1380.58 | 125.51 | |
| Sampling | 72 | 1707.50 | 23.72 | |
| LYING RUMINATING | | | | |
| Total | 95 | 1816.50 | | |
| Replications | 1 | 20.17 | 20.17 | |
| Species | 2 | 466.19 | 233.09 | 7.56 ** |
| Intensity | 1 | 35.04 | 35.04 | 1.14 |
| S x I | 2 | 33.52 | 16.76 | .54 |
| Months | 1 | 77.04 | 77.04 | 2.50 |
| M x S | 2 | 86.90 | 43.45 | 1.41 |
| M x I | 1 | .17 | .17 | .01 |
| M x I x S | 2 | 124.40 | 62.20 | 2.02 |
| Error | 11 | 339.08 | 30.83 | |
| Sampling | 72 | 634.00 | 8.81 | |

Table 22 continued

| ACTIVITY<br>Source of variation | df | Sum of squares | Mean squares | F ratios |
|---|---|---|---|---|
| STANDING IDLE | | | | |
| Total | 95 | 138.50 | | |
| Replications | 1 | 10.67 | 10.67 | |
| Species | 2 | 3.81 | 1.91 | .66 |
| Intensity | 1 | 0.00 | 0.00 | .00 |
| S x I | 2 | 1.56 | .78 | .27 |
| Months | 1 | 18.38 | 18.38 | 6.40 * |
| M x S | 2 | 3.81 | 1.91 | .66 |
| M x I | 1 | .04 | .04 | .01 |
| M x I x S | 2 | .65 | .32 | .11 |
| Error | 11 | 31.58 | 2.87 | |
| Sampling | 72 | 68.00 | .94 | |
| LYING IDLE | | | | |
| Total | 95 | 12.16 | | |
| Replications | 1 | .09 | .09 | |
| Species | 2 | 1.19 | .59 | 2.35 |
| Intensity | 1 | .01 | .01 | .04 |
| S x I | 2 | .15 | .07 | .29 |
| Months | 1 | .01 | .01 | .04 |
| M x S | 2 | .15 | .07 | .29 |
| M x I | 1 | .26 | .26 | 1.03 |
| M x I x S | 2 | .27 | .14 | .54 |
| Error | 11 | 2.78 | .25 | |
| Sampling | 72 | 7.25 | .10 | |
| TRAVELING | | | | |
| Total | 95 | 269.49 | | |
| Replications | 1 | 44.01 | 44.01 | |
| Species | 2 | 16.40 | 8.20 | 1.56 |
| Intensity | 1 | .01 | .01 | .00 |
| S x I | 2 | 1.65 | .82 | .16 |
| Months | 1 | 36.26 | 36.26 | 6.89 * |
| M x S | 2 | 2.02 | 1.01 | .19 |
| M x I | 1 | 5.51 | 5.51 | 1.05 |
| M x I x S | 2 | 5.02 | 2.51 | .48 |
| Error | 11 | 57.86 | 5.26 | |
| Sampling | 72 | 100.75 | 1.40 | |

* and ** indicate significance at the 95% and 99% level of confidence, respectively.

Table 23. Mean daily time spent by sheep in each of six activities on foothill range at Tintic for each treatment, 1966.

| | Activities | | | | | |
|---|---|---|---|---|---|---|
| | | Ruminating | | Idling | | |
| Situation | Feeding | Standing | Lying | Standing | Lying | Traveling |
| | minutes | | | | | |
| Treatments (Native + species x intensities) | | | | | | |
| Native | 478* | 216 | 141 | 31 | 13 | 21 |
| Cr Lt | 661 | 200 | 14 | 3 | 0 | 21 |
| Cr Hy | 664 | 185 | 22 | 6 | 1 | 22 |
| In Lt | 672 | 198 | 14 | 5 | 0 | 11 |
| In Hy | 674 | 165 | 42 | 5 | 0 | 14 |
| Tl Lt | 580 | 221 | 69 | 11 | 3 | 15 |
| Tl Hy | 610 | 200 | 69 | 8 | 2 | 11 |
| Average | 620 | 198 | 53 | 10 | 3 | 16 |
| Species (Seeded wheatgrasses) | | | | | | |
| Crested | 662 | 192 | 18 | 5 | 0.3 | 22 |
| Intermediate | 673 | 181 | 28 | 5 | 0 | 12 |
| Tall | 595 | 211 | 69 | 9 | 0.2 | 13 |
| Intensities (Initial stocking based on sheep numbers) | | | | | | |
| Light | 638 | 206 | 33 | 6 | 1 | 16 |
| Heavy | 649 | 183 | 45 | 6 | 1 | 16 |
| Months | | | | | | |
| May | 620 | 195 | 44 | 16 | 3 | 22 |
| June | 620 | 201 | 63 | 3 | 2 | 11 |
| Replications (Separate pastures of 7 treatments) | | | | | | |
| 1 | 621 | 185 | 55 | 14 | 3 | 21 |
| 2 | 618 | 211 | 52 | 5 | 2 | 12 |

* Means for the native treatment were statistically different at 95% level by Duncan range test from each of the other treatments for all activities except standing ruminating. No other comparisons were significantly different by Duncan range test.

Duncan multiple range test. Likewise, no differences in means were found due to months for the standing idle and traveling activities, which did produce significant F-tests in analysis of variance.

Shade effects in seeded pastures. After the sheep were noted to begin afternoon feeding earlier than in the preliminary study on hot days in seeded pastures with little or no shade, the seeded pastures were rated on a 0 to 9 scale for shade abundance and location in the pasture. Considering the seeded pastures only, the number of scans for each activity were regressed on the shade ratings for the pastures. Only lying ruminating produced a significant coefficient of determination (Table 24). In some seeded pastures the availability of shade near at hand where sheep stopped morning feeding may have contributed to an increase in the amount of time sheep spent lying ruminating. Since the analysis for lying idle showed little correlation with shade rating, the regression on shade rating for the combination of both lying activities produced a similar coefficient of determination as did the lying ruminating activity alone.

## Effects of environmental factors

Temperature, relative humidity, cloudiness, and wind movement explained less than 31% of the variation in any of the sheep activities in this study. Averaged across all activities, temperature contributed most to the coefficients of multiple determination, followed by relative humidity, cloudiness, and wind movement. In spite of the low coefficients of determination, some F-tests of regression mean squares nd residual mean square ratios were highly significant, even with a decision criterion of four times the appropriate tabular F value.

Table 24. Simple linear regressions of activity times on availability of shade on foothill range in central Utah, for 12 seeded pastures.

| Activity | Regression coefficients ($b_i$) | Coefficients of determination ($r^2$) |
|---|---|---|
| Feeding | -.72 | .09 |
| Standing ruminating | -.18 | .01 |
| Standing idle | -.02 | .00 |
| Lying ruminating | .94 | .46 |
| Lying idle | .03 | .14 |
| Combined lying | .47 | .46 |
| Traveling | -.06 | .02 |

Both lying activities were positively related to relative humidity. Traveling and standing idle decreased, but feeding time increased with higher mean daily temperature.

Feeding time. Multiple regression of time spent feeding on the environmental factors produced the largest coefficient of determination of all activities studied (Table 25). With all four factors in the model, $R^2$ was .304. The stepwise deletion procedure first eliminated humidity as a factor, leaving the 3-factor model with an $R^2$ of .275 and all three factors positively correlated with daily feeding time. The 2-factor analysis included cloudiness and temperature. Finally, ambient temperature remained as the factor most related with feeding time. Daily feeding time was approximately 60 minutes greater for each 10 F increase in mean daily temperature.

Four measures of ambient temperature--daily mean, peak daily temperature, and temperatures when morning and afternoon feeding began--were analyzed separately for effect on daily feeding time at each location individually and at both locations combined. These analyses indicated no relation between temperature and feeding time on the foothill location (Table 26). On the mountain location mean daily temperature explained 32% of the variation in daily feeding time.

Standing ruminating. In the analyses of standing ruminating in relation to environmental factors all models and single factors at each stage lacked significance (Table 27).

Lying ruminating. Relative humidity was the most predictive environmental factor for daily time spent lying ruminating by the sheep under these study conditions (Table 28).

Table 25. Regression of daily feeding time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 100.84 | | |
| V1# | (1) | 1858.72 | 26.01 + | 4.2300 |
| V2 | (1) | 794.71 | 11.12 | 4.1356 |
| V3 | (1) | 740.56 | 10.36 | .3563 |
| V4 | (1) | 657.57 | 9.20 | - .1989 |
| Model | 4 | 1708.44 | 23.90 ++ | 20.0742 = $b_0$ |
| Residual | 219 | 71.47 | $R^2$ = .304 | |
| V1 | (1) | 1439.91 | 19.42 + | 3.6072 |
| V2 | (1) | 1195.47 | 16.12 + | 4.9516 |
| V3 | (1) | 3115.28 | 42.02 ++ | .5677 |
| Model | 3 | 2058.72 | 27.77 ++ | - .9716 = $b_0$ |
| Residual | 220 | 74.14 | $R^2$ = .275 | |
| V1 | (1) | 1317.90 | 16.64 + | 3.4469 |
| V3 | (1) | 2830.55 | 35.73 ++ | .5394 |
| Model | 2 | 2490.35 | 31.44 ++ | 15.2521 = $b_0$ |
| Residual | 221 | 79.21 | $R^2$ = .222 | |
| V3 | (1) | 3662.81 | 43.20 ++ | .6041 |
| Model | 1 | 3662.81 | 43.20 ++ | 14.2030 = $b_0$ |
| Residual | 222 | 84.79 | $R^2$ = .163 | |

# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

\+ F ratio more than four times F-value for 95% level

++ F ratio more than four times F-value for 99% level

Table 26. Simple linear regressions of feeding time of sheep on various measures of temperature.

| Temperature measures | Regression coefficients ($b_1$) | Coefficients of determination ($r^2$) |
|---|---|---|
| MOUNTAIN SITE | | |
| Mean daily temperature | .80 | .32 |
| Temperature at start of AM feeding | .66 | .28 |
| Temperature at start of PM feeding | .56 | .21 |
| Peak daily temperature | .53 | .20 |
| FOOTHILL SITE | | |
| Peak daily temperature | -.16 | .02 |
| Temperature at start of AM feeding | -.15 | .02 |
| Temperature at start of PM feeding | -.09 | .01 |
| Mean daily temperature | -.06 | .00 |
| COMBINED SITES | | |
| Peak daily temperature | .58 | .22 |
| Mean daily temperature | .60 | .18 |
| Temperature at start of PM feeding | .45 | .15 |
| Temperature at start of AM feeding | -.18 | .01 |

Table 27. Regression of daily standing ruminating time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 51.04 | | |
| V1# | (1) | 67.78 | 1.35 | - .8078 |
| V2 | (1) | 34.40 | .68 | .8605 |
| V3 | (1) | 50.97 | 1.01 | - .0935 |
| V4 | (1) | 140.40 | 2.79 | - .0919 |
| Model | 4 | 91.00 | 1.81 | 27.0982 = $b_0$ |
| Residual | 219 | 50.31 | $R^2$ = .032 | |
| V1 | (1) | 67.06 | 1.13 | - .8034 |
| V4 | (1) | 180.67 | 3.60 | - .1018 |
| V3 | (1) | 71.67 | 1.43 | - .1087 |
| Model | 3 | 109.86 | 2.19 | 30.8290 = $b_0$ |
| Residual | 220 | 50.24 | $R^2$ = .029 | |
| V4 | (1) | 256.67 | 5.10 | - .1174 |
| V3 | (1) | 127.97 | 2.54 | - .1390 |
| Model | 2 | 131.27 | 2.61 | 32.5009 = $b_0$ |
| Residual | 221 | 50.31 | $R^2$ = .023 | |
| V4 | (1) | 134.56 | 2.66 | - .0691 |
| Model | 1 | 134.56 | 2.66 | 21.8100 = $b_0$ |
| Residual | 222 | 50.66 | $R^2$ = .012 | |

# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

Table 28. Regression of daily lying ruminating time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 44.79 | | |
| V1# | (1) | 524.44 | 15.58 | -2.2469 |
| V2 | (1) | 679.35 | 20.19 + | -3.8237 |
| V3 | (1) | .17 | .01 | .0054 |
| V4 | (1) | 795.16 | 23.63 + | .2188 |
| Model | 4 | 654.31 | 19.44 ++ | 16.0010 = $b_0$ |
| Residual | 219 | 33.65 | $R^2$ = .262 | |
| V1 | (1) | 564.82 | 16.86 + | -2.2354 |
| V2 | (1) | 711.39 | 21.24 + | -3.8356 |
| V4 | (1) | 1293.46 | 38.61 ++ | .2168 |
| Model | 3 | 872.35 | 26.04 ++ | 16.4413 = $b_0$ |
| Residual | 220 | 33.50 | $R^2$ = .262 | |
| V4 | (1) | 1150.99 | 32.66 ++ | .2036 |
| V2 | (1) | 648.97 | 18.08 + | -3.6586 |
| Model | 2 | 1026.12 | 28.58 ++ | 14.0703 = $b_0$ |
| Residual | 221 | 35.90 | $R^2$ = .206 | |
| V4 | (1) | 1403.27 | 36.29 ++ | .2230 |
| Model | 1 | 1403.27 | 36.29 ++ | 3.1558 = $b_0$ |
| Residual | 222 | 38.67 | $R^2$ = .141 | |

\# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

\+ F ratio more than four times F-value for 95% level

++ F ratio more than four times F-value for 99% level

The sheep spent more time lying ruminating on days that were humid and still.

Standing idle. Standing idle time was negatively related to mean daily temperature (Table 29). Within the range of daily conditions encountered in this study, 3-34 C (37-94 F), the sheep spent 16 minutes more time standing idle for each 10 F decrease in mean daily temperature.

Lying idle. Like lying ruminating, the amount of time the sheep spent lying idle was most associated with relative humidity (Table 30). Lying idle was more common on days that were humid and still.

Traveling. Temperature explained more of the variation, 19%, in daily traveling time than was true of any other single factor for any activity (Table 31). The sheep traveled 16 minutes less daily for each 10 F increase in mean daily temperature.

Native versus seeded range

The number of scans recorded for each activity did not differ between native foothill pastures and the mountain range situation in this study (Table 32). Feeding occupied more of the sheep day on the seeded foothill pastures than on either native foothill range or the mountain range. On the other hand, the sheep spent less time lying ruminating and either standing or lying idle on the seeded foothill pastures. The sheep traveled more while not feeding on the mountain location than they did on seeded foothill pastures. This study detected no difference in standing ruminating time due to location or forage type on foothill range.

Table 29. Regression of daily standing idle time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 9.02 | | |
| V1# | (1) | 108.40 | 14.69 | -1.0215 |
| V2 | (1) | 16.36 | 2.22 | - .5933 |
| V3 | (1) | 136.53 | 18.50 + | - .1530 |
| V4 | (1) | .68 | .09 | - .0064 |
| Model | 4 | 99.11 | 13.43 + | 15.7862 = $b_0$ |
| Residual | 219 | 7.38 | $R^2$ = .197 | |
| V1 | (1) | 120.05 | 16.33 + | -1.0415 |
| V2 | (1) | 15.68 | 2.13 | - .5671 |
| V3 | (1) | 206.60 | 28.11 ++ | - .1462 |
| Model | 3 | 131.91 | 17.95 ++ | 15.1104 = $b_0$ |
| Residual | 220 | 7.35 | $R^2$ = .197 | |
| V1 | (1) | 116.13 | 15.74 + | -1.0232 |
| V3 | (1) | 198.82 | 26.94 + | - .1430 |
| Model | 2 | 190.03 | 25.75 ++ | 13.2522 = $b_0$ |
| Residual | 221 | 7.38 | $R^2$ = .189 | |
| V3 | (1) | 263.93 | 33.54 ++ | - .1622 |
| Model | 1 | 263.93 | 33.54 ++ | 13.5636 = $b_0$ |
| Residual | 222 | 7.87 | $R^2$ = .131 | |

# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

\+ F ratio more than four times F-value for 95% level

++ F ratio more than four times F-value for 99% level

Table 30. Regression of daily lying idle time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 2.39 | | |
| V1# | (1) | .85 | .42 | - .0903 |
| V2 | (1) | 9.72 | 4.86 | - .4574 |
| V3 | (1) | 6.69 | 3.35 | .0339 |
| V4 | (1) | 63.47 | 31.74 ++ | .0618 |
| Model | 4 | 24.09 | 12.04 + | -1.7423 = $b_0$ |
| Residual | 219 | 2.00 | $R^2$ = .181 | |
| V4 | (1) | 63.81 | 32.07 ++ | .0600 |
| V2 | (1) | 9.77 | 4.91 | - .4584 |
| V3 | (1) | 5.88 | 2.95 | .0304 |
| Model | 3 | 31.84 | 16.00 ++ | -1.5500 = $b_0$ |
| Residual | 220 | 1.99 | $R^2$ = .179 | |
| V4 | (1) | 66.85 | 33.26 ++ | .0491 |
| V2 | (1) | 13.67 | 6.80 | - .5310 |
| Model | 2 | 44.82 | 22.30 ++ | -1.0065 = $b_0$ |
| Residual | 221 | 2.01 | $R^2$ = .168 | |
| V4 | (1) | 75.96 | 36.87 ++ | .0519 |
| Model | 1 | 75.96 | 36.87 ++ | - .5774 = $b_0$ |
| Residual | 222 | 2.06 | $R^2$ = .140 | |

# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

\+ F ratio more than four times F-value for 95% level

++ F ratio more than four times F-value for 99% level

Table 31. Regression of daily traveling time by sheep on four environmental factors on mountain and foothill range.

| SV | df | MS | F | b |
|---|---|---|---|---|
| Total | 223 | 6.42 | | |
| V1# | (1) | .30 | .06 | - .0540 |
| V2 | (1) | .42 | .08 | - .0946 |
| V3 | (1) | 128.05 | 24.30 + | - .1482 |
| V4 | (1) | 4.71 | .89 | .0168 |
| Model | 4 | 69.86 | 13.26 | 12.6208 = $b_0$ |
| Residual | 219 | 5.27 | $R^2$ = .195 | |
| V4 | (1) | 4.41 | .84 | .0158 |
| V2 | (1) | .42 | .08 | - .0952 |
| V3 | (1) | 143.22 | 27.33 + | - .1502 |
| Model | 3 | 93.05 | 17.76 ++ | 12.7358 = $b_0$ |
| Residual | 220 | 5.24 | $R^2$ = .195 | |
| V4 | (1) | 5.29 | 1.01 | .0169 |
| V3 | (1) | 146.15 | 28.00 ++ | - .1486 |
| Model | 2 | 139.36 | 26.70 ++ | 12.3240 = $b_0$ |
| Residual | 221 | 5.22 | $R^2$ = .195 | |
| V3 | (1) | 273.44 | 52.38 ++ | - .1651 |
| Model | 1 | 273.44 | 52.38 ++ | 13.8641 = $b_0$ |
| Residual | 222 | 5.22 | $R^2$ = .191 | |

# V1 = Cloudiness, V2 = Wind movement, V3 = Temperature, V4 = Relative humidity

+ F ratio more than four times F-value for 95% level

++ F ratio more than four times F-value for 99% level

Table 32. Comparison of mean minutes per day spent by sheep for each activity on mountain range, native foothill range, and seeded foothill range.

| Activity | Mountain range | Foothill Native range | Foothill Seeded pastures |
|---|---|---|---|
| Feeding | 490a* | 478a | 640b |
| Standing ruminating | 205a | 216a | 195a |
| Lying ruminating | 119a | 141a | 38b |
| Standing idle | 40a | 31a | 6b |
| Lying idle | 11a | 13a | 1b |
| Traveling | 35a | 21ab | 16b |

* Within each activity means with the same letter do not differ at the 95% level of significance.

Sheep postures

While grazing seeded foothill pastures the study sheep spent 94% of their time standing or moving about and only 6% of their time lying down (Table 33). On mountain range the sheep spent more time lying than they did at the foothill location on seeded pastures. Sheep spent considerably more time ruminating on the mountain location than at the foothill pastures. Most of the additional ruminating was performed while the sheep were lying.

Sheep performance during study

Ewes gained 125 g per day in May on the seeded pastures, while those grazing native foothill range lost 45 g daily (Table 34). The ewes lost weight in June on all treatments except heavy stocked tall wheatgrass. The sheep from each foothill treatment gained weight on mountain range. As a group the sheep had a total gain for the study period of about 3.1 kg each from May through early September. For the total period at both locations ewes on crested wheatgrass in May and June gained the least and those ewes on intermediate wheatgrass the most. Lamb gains were 16-17 kg per lamb from June through early September regardless of foothill treatment.

Table 33. Time spent by sheep in specified activities during 15-hour days in 1966 on central Utah foothill and mountain range types.

| | Postures | | | | | |
|---|---|---|---|---|---|---|
| | Standing | | Lying | | Total | |
| Activity | minutes | percent | minutes | percent | minutes | percent |
| | | | Foothill range | | | |
| Feeding | 620 | 69 | | | 620 | 69 |
| Ruminating | 198 | 22 | 53 | 6 | 251 | 28 |
| Idling | 10 | 1 | 3 | 0 | 13 | 1 |
| Traveling | 16 | 2 | | | 16 | 2 |
| Totals | 844 | 94 | 56 | 6 | 900 | 100 |
| | | | Mountain range | | | |
| Feeding | 490 | 54 | | | 490 | 54 |
| Ruminating | 205 | 23 | 119 | 13 | 324 | 36 |
| Idling | 40 | 4 | 11 | 1 | 51 | 5 |
| Traveling | 35 | 4 | | | 35 | 4 |
| Totals | 770 | 86 | 130 | 14 | 900 | 100 |

Table 34. Average daily gains in grams for ewes and lambs on three species of wheatgrass grazed at two intensities and native foothill range at Tintic and subsequent summer mountain range at Scofield in 1966.*

| Species | Intensity | Class of animals | Foothill May | Foothill June | Mountain |
|---|---|---|---|---|---|
| Native | | Ewes | -45 | -18 | 73 |
| | | Lambs | | 186 | 155 |
| Crested wheatgrass | Light | Ewes | 200 | -177 | 23 |
| | | Lambs | | 241 | 136 |
| | Heavy | Ewes | 159 | -141 | 23 |
| | | Lambs | | 209 | 155 |
| Intermediate wheatgrass | Light | Ewes | 141 | - 18 | 5 |
| | | Lambs | | 227 | 141 |
| | Heavy | Ewes | 136 | - 45 | 8 |
| | | Lambs | | 209 | 141 |
| Tall wheatgrass | Light | Ewes | 55 | - 18 | 18 |
| | | Lambs | | 214 | 155 |
| | Heavy | Ewes | 59 | 32 | 14 |
| | | Lambs | | 195 | 155 |

* Data taken from Utah State University Range Science Department Project 690 files in summarized form. It is not clear whether May gains of ewes were adjusted for weight loss from the lambing process in early May.

# DISCUSSION AND CONCLUSIONS

## Test of Hypotheses

### Hypothesis A

The first null hypothesis tested was that sheep spend the same amount of time in specified activities during the day on foothill and mountain range. This hypothesis and its alternative, that sheep activities differ on mountain and foothill locations, were entertained for each activity separately. The null hypothesis A was accepted for standing ruminating but rejected for all other activities, which accounted for different portions of the observation day on the foothill pastures compared with mountain range in central Utah. Explanations of these differences vary among the activities.

Feeding. The sheep spent more time feeding on foothill range in May and June than they did in subsequent months on mountain range (Table 35). Limitations of the study by confounding of many factors with changes from foothill to mountain range prevented the determination of causes of differences in feeding time as well as other activities. Although the same sheep were observed at the two locations, the sheep were in different stages of production. Also the types of forage available, the type and distribution of shade, weather factors and daylength varied between the two locations.

The foothill study began with the sheep in late stages of pregnancy and continued through lambing and the early stages of lactation. Later on mountain range the sheep were in late stages of lactation and continued beyond weaning of lambs. As Arnold and Dudzinski (1978) pointed

Table 35. Comparison of time budgets of ewes with data from other sheep activity studies on range.

| Activity | Cory[a] | Bowns[b] | Doran[c] | Rodgers Summer Mountain | Rodgers Spring Foothill |
|---|---|---|---|---|---|
| | minutes | | | | |
| Recorded day | 792 | 840 | 870 | 900 | 900 |
| Feeding | 397 | 594 | 408 | 490 | 620 |
| Resting | 288 | 213 | 343 | 375 | 264 |
| Standing ruminating | 78 | – | – | 205 | 198 |
| Lying ruminating | – | – | – | 119 | 53 |
| Lying idle | 120* | – | – | 11 | 3 |
| Standing idle | 90 | – | – | 40 | 10 |
| Traveling | 102 | 33 | 108 | 35 | 16 |
| Distance moved | 6116 m | 3862 m | – | 2980 m | 2910 m |

[a] Cory 1927; [b] Bowns 1971; [c] Doran 1943

* Cory recorded lying resting time, but it is not clear whether this included some ruminating time while lying.

out, sheep in lactation may spend more time feeding, take more bites of forage per unit of time while feeding and take larger bites of forage while feeding to increase their intake and meet their greater energy requirements. Much of the differences in feeding at the two locations may have been due to these differences in stage of lactation. Arnold and Dudzinski (1978) reported a 12% increase in feeding time due to lactation while the sheep in this study spent 26% more time feeding on foothill range than they spent on mountain range.

The lack of shade in the vicinity of water in most seeded pastures may have triggered earlier initiation of afternoon feeding on foothill pastures. In the absence of shade the sheep chose to return to feeding rather than stand or lie in the heat without protection from the sun. This early afternoon feeding was frequently interrupted, less intense, and less synchronous than feeding at other times. While not tested in this study, the lack of sufficient shade for the entire herd to rest simultaneously may have prompted individual feeding. The sheep fed more each day, on the average, than the sheep studied by Cory (1927) and Doran (1943) but about the same as those observed by Bowns (1971) in southern Utah (Table 35).

In each half of the mountain grazing season the sheep began afternoon feeding about 370 minutes, on the average, after the cessation of morning feeding. Thus, some of the additional feeding time in the first half of the summer on mountain range may have been due to the timing of the earlier morning feeding permitted by the earlier sunrise associated with longer daylength during that part of the grazing season. Both daylength and daily feeding time in my study were greater for the foothill location. Squires (1974) also concluded that increased sheep feeding in his situation was due to seasonal changes in daylength as did Reppert (1960) for cattle grazing in Colorado.

The higher feeding time in the first half of the summer on mountain range followed a period of under-nutrition on foothill pastures in June as revealed by the sheep weight losses at that time (Table 34). Arnold and Birrell (1977) found higher dry organic matter intake by increases in both the rate of intake and the time spent grazing by sheep after periods of weight loss.

Lying ruminating. Sheep spent less time lying ruminating in May and June on foothill range than they did in subsequent months on mountain range. Welch and Smith (1969a, 1969b) have suggested that ruminating time exhibits a curvilinear response to intake of forage cell wall constituents. If the total 24-hour day had been recorded in this study the sheep would have been expected to increase ruminating time the same days they spent more time feeding. Since only the daylight hours were studied my data represent primarily the ruminating time required following the morning feeding periods. Much of the increased feeding time on the foothill location came during the afternoon and served to reduce the length of the midday period available for ruminating and idling. Little can be said about the impact of the increased feeding time upon total rumination time that may have occurred during the night. Forage quality was not determined in this study as a basis for projections of ruminating time needed in relation to feeding time.

Lying ruminating generally was recorded only during the midday period when the entire flock was shaded up and still. A minor amount of lying ruminating was observed at either end of the active day.

Animals that were lying ruminating often arose when other sheep moved about or began feeding individually.

The lying resting activity reported by Cory (1927) was not synonymous with lying ruminating in this study, but he recorded a similar amount of time in that activity as I did for lying ruminating on the mountain range location. Neither Bowns (1971) nor Doran (1943) distinguished lying ruminating from other resting and idling, Dwyer (1961) noted a similar amount of lying ruminating time during the active day of cows in Oklahoma as I recorded for sheep on mountain and native foothill range in Utah.

Idling. Sheep on mountain range spent a little more time idling than they did on foothill pastures including standing idle and lying idle activities. Idling activities were most common just prior to feeding and after a bout of rumination. Time devoted to idling was probably a result of the combination of time needed for rumination in midday and the initiation of afternoon feeding. Although idling may be mostly a residual activity there was also the need for panting on hot days which required that sheep spend time idling instead of ruminating. Sheep did not ruminate and pant simultaneously. Perhaps I should have recorded panting as a separate activity to learn more about the environmental effects on sheep activities. Notes recorded during the preliminary study in 1965 indicated that sheep panted on those days when ambient temperature exceeded 22 C. A temperature of 22 C was exceeded on 26 of 28 days on foothill range and on 12 of 28 days on mountain range during the principal study in 1966. In spite of the warmer conditions on foothill range the sheep spent less time idling there than they did on mountain range. Feeding and ruminating activities on foothill range left only 30 minutes daily for idling and traveling. Others who have studied sheep under similar conditions did not separate idling as an activity (Bowns 1971, Doran 1943, Cory 1927).

Traveling. The sheep traveled slightly more on mountain range than in foothill pastures. Much of the greater traveling time on mountain range was probably related to the distance from midday rest areas at the time morning feeding stopped on mountain range. On the 25 ha seeded foothill pastures the sheep often continued feeding right up to the water troughs. Additional travel on mountain range also occurred as the flock moved up sloping crests of ridges to selected nightly bedgrounds.

Both Cory (1927) and Doran (1943) recorded more time traveling by sheep during the active day than I did at either location. Travel while not feeding reduces efficiency of livestock production. Desirable midday ruminating and idling sites need to be so located that such traveling is not necessary.

Hypothesis B

The second null hypothesis tested in this investigation predicted that sheep activities would be the same on seeded and native foothill pastures. Hypothesis B was rejected for all activities except traveling and standing ruminating. Feeding time was greater on the seeded pastures than on the native foothill pastures where the time budget of sheep was similar to that of sheep on the mountain range later in the year (Table 32). The ewes on seeded wheatgrass pastures spent less time lying ruminating and lying idle than the ewes on the two native foothill pastures.

Feeding. Sheep on native foothill pastures spent much less time feeding daily than ewes on seeded foothill pastures. Arnold (1964) found that, usually, sheep increased their grazing time to compensate for lack of available green forage but that grazing time decreased when green forage was less than 560 kg/ha. Although forage availability was not measured during this study it should be noted that palatable forage was certainly below the critical amount suggested by Arnold (1964) on the native foothill pastures. In the native pastures big sagebrush was the predominant forage available. Previous records of production on the seeded pastures (Cook 1965) suggests that a greater amount of green forage was available there. Since the study was conducted during the period of rapid growth of the seeded species, it is doubtful if forage availability declined on the seeded pastures during the course of study there even though utilization was gradually increasing. Arnold (1960) has suggested that sheep may increase their feeding time to maintain intake when forage availability declines in a pasture. Krueger (1970) noted that sheep selected preferred forage by sight but moved on if selection was not reinforced by other senses. On native foothill range in my study the ewes may have simply fed across the native pastures more rapidly as they foraged and reached preferred resting areas earlier in the feeding periods, where they remained until increasing appetite late in the day overcame their lack of preference for the available forage plants in the native pastures. The ewes lost weight in both May and June on native foothill range, and their lambs gained less than those on seeded pastures.

Ruminating. While standing ruminating time did not differ between native and seeded foothill range, lying ruminating and total rumination time were both different. Ewes ruminated about two hours more daily on native range than they did on seeded pastures, with most of the difference due to increased lying ruminating. The fact that sheep spent more time ruminating on native pastures than on seeded pastures may have been due to the greater time not feeding at their disposal, but some of the increase in ruminating time may have been needed if the native pasture forage was of poorer quality. Welch and Smith (1969a) have indicated that rumination is an important process in promoting passage of coarse fibrous material from the rumen, and may be a factor in limiting intake of poor quality forages. Under continuous feeding conditions Welch and Smith (1969b) noted a curvilinear response of ruminating time to intake of forage. They found that as the fibrous load increased, rumination time decreased per unit of dry matter or cell wall constituents. Possible explanations were that rumination is more efficient in reducing particle size as the load increases, that other means of reducing particle size (such as microbial digestion) becomes more important, or that the reticule-omasal orifice may accept larger particles as the rumen fiber load increases.

On native foothill range the sheep had access to more abundant and more evenly distributed shade for midday ruminating and idling than the sheep on most of the seeded pastures. Squires (1973) found that sheep in two situations in Australia bedded in midday, choosing thickets of taller brush in saltbush pasture and utilizing the shade of scattered trees in a grassland pasture.

Idling. The sheep spent very little time idling on foothill range, but spent more time idling on native than on seeded pastures. Since idling totaled only 44 minutes per day even on native range pastures this component of the sheep's day may be of significance only when the sheep need to pant under heat stress or to care for their lambs. For both types of pasture the sheep spent about five times as many minutes standing idle in May as they did in June, particularly during the first weeks of May. Davey and Holmes (1977) noted a considerable increase in standing just after shearing which led to a large increase in energy expenditure. The sheep in this study were sheared just prior to being moved to the study pastures about May 1.

Hypothesis C

The third hypothesis entertained in the investigation was that sheep activities are not different on three selected seeded species--crested, intermediate, and tall wheatgrass. Hypothesis C was accepted for each activity. None of the seeded species caused activities to differ significantly from other species (Table 23). Estimates of mean feeding time were less and those for lying ruminating more for sheep on tall wheatgrass than corresponding values for sheep on crested and intermediate wheatgrass. These differences were not statistically significant. Additional study under more precise methods might show that sheep would reach rumen fill more quickly and require more time for rumination when feeding on the coarser tall wheatgrass as suggested by the research of Conrad (1966), Pigden and Bender (1972), and Welch and Smith (1969a, 1969b).

Hypothesis D

The fourth null hypothesis tested in this study predicted that stocking rate would have no effect on sheep activities on foothill range. The null hypothesis was accepted for each activity. Stocking rate, varied by changing the number of ewes in similar size pastures, had no effect on the amount of time sheep spent in any of the six activities (Table 23).

Ewe numbers in the individual pastures varied from 32 to 111 with an average of 39 ewes on lightly stocked pastures and 80 ewes on heavily stocked pastures. Utilization achieved by the end of the season ranged from 28% to 64% on individual pastures, and averaged 47% on lightly stocked pastures and 58% on the heavily stocked pastures. Separate simple regressions of activity times on utilization actually obtained rather than the planned intensity of use still required acceptance of null hypothesis D.

Other studies of the effects of stocking rate on livestock activities, mostly with cattle, have found no effect on time spent in the various activities due to grazing intensity aside from the long term effects of such stocking rates on the vegetative composition of the pastures (Hubbard 1952, Hancock 1954, Peterson and Woolfolk 1955, Smith 1959). Arnold (1960, 1964) notes a reduction in rumination time as forage availability declines and an increase in grazing time in response to declining availability of green forage.

Hypothesis E

The final null hypothesis entertained in this investigation was that the time sheep spend in specified daily activities is not affected by changes encountered in selected environmental factors. In spite of significant regressions discovered for several combinations of activities and weather factors the null hypothesis E was not rejected. Confounding of weather factors with varying range situations and the low coefficients of determination suggests that the null hypothesis should not be rejected pending further investigation under more strictly controlled conditions. Weather factors varied only within a very narrow and temperate range during the study. Greater extremes in weather conditions might have produced significant responses in daily time budgets of sheep. Nevertheless, some of the apparent relationships were of interest.

Temperature. Sheep fed more on foothill range, where the mean daily temperature was warmer, than they did on the cooler mountain location. None of the temperature and feeding relationships, however, were strong enough to have any predictive value. Regressions of all activities on various measures of temperature (the daily mean, daily maximum, and temperatures at the start of both morning and afternoon feeding) were examined for possible influences on activities, both for the two locations combined and each separately. Regression analyses for effects of temperature on sheep feeding time on foothill ranges yielded essentially zero relationships. On the mountain location where the sheep fed much less under the cooler conditions, there was a significant positive regression of feeding time on temperature. None of the temperature measures explained more than one-third of the variation in feeding time (Table 26). Malechek and Smith (1976) found that cows spent more time grazing and less time standing on warmer days during the winter in northern Utah, while in Australia Lynch (1974), noted that sheep prolonged rest during midday when temperatures were high.

The higher temperature and greater feeding time during the first half of the summer on mountain range resulted as the sheep began to feed about 30 minutes earlier in the afternoon and, perhaps due to the later sunset, fed about 30 minutes later each evening. Examination of the field data indicated that the sheep began afternoon feeding after the daily peak temperature had occurred. On the average the daily peak temperature was reached 30 minutes earlier during the first half of the mountain grazing period than during the late season. Lynch (1974) reported that sheep resumed feeding by 1800 hours even when the temperature exceeded 40 C. Arnold and Dudzinski (1978) suggested that sheep are sensitive to daylength by relating the start of afternoon feeding to the time of sunset, but I found no such relationship.

Panting and shivering are two mechanisms sheep use to adjust to extremes in temperature. Both activities generally occur while the sheep is standing idle and might affect the time devoted to standing idle. In this study the sheep panted only while idle and Bennett (1972) has noted that sheep prefer to stand when exposed to cold perhaps as a way of producing greater energy expenditure to temporarily warm the body even though heat loss is greater when standing.

The ewes panted to dissipate heat through respiratory evaporation on hot days on foothill and mountain range. Symington (1960) stated that this is the most important cooling mechanism for sheep. Knapp and Robinson (1954) found that such respiratory water loss could account for one-third of the total water loss. I found that ewes panted at lower ambient temperatures than reported by Blaxter et al (1959a). Perhaps this was due to shorter fleeces providing less insulation.

The ewes were observed shivering on several cool mornings on both foothill and mountain locations with ambient temperatures around 8 C, the point at which Armstrong et al (1960) noted a metabolism rise unless fleeces of the sheep were longer than 33mm. The ewes in this study were sheared in late April, but the length of their fleeces were not measured during the study. Graham et al (1959) found that closely clipped sheep on a medium feeding regime at 8 C showed twice the minimum metabolism. Blaxter et al (1959a) noted more shivering at a temperature of 11 C than was observed in this study. Most of the sheep were in a positive energy balance in May and then again on mountain range as reflected by their average daily gains in those periods of the study (Table 34).

Relative humidity. Lying ruminating and lying idle both showed positive regression on relative humidity. Both lying activities were more common on mountain range than on the foothill site. Relative humidity was higher on the mountains, where the sheep spent the same amount of time standing ruminating as on the foothills but spent most of the longer midday period lying ruminating. Relative humidity serves to exaggerate the effects of temperature by changing the evaporative cooling power of the air. Ehrenreich and Bjugstad (1966) found that cattle grazing time responded to a combination of temperature and humidity as expressed in an index of both factors, but I did not.

Cloudiness and wind movement. Little influence was noted for wind movement and cloud cover on the time sheep spent in any activity. The sheep were seen to seek the leeward side of brushpiles for non-feeding activities on the windiest days on foothill pastures, but the sheep did not change the time spent in the activities. Likewise, direct sunshine may have affected the distribution of sheep relative to shade, wind direction, and each other, but did not cause a change in time allocation to the six activities studied.

Malechek and Smith (1976) reported that cows traveled shorter distances on cold days, but no such effect was observed in this study.

## General Behavior

### Bimodal feeding

Sheep fed twice daily in all situations investigated with the timing of the feeding periods related to sunrise and sunset. Length of the midday ruminating and idling period was very uniform at each location. Differences between locations were probably due to the need for rumination during the day and the availability of shade. On the seeded foothill pastures the ewes began afternoon feeding earlier and less synchronously than on either native foothill or mountain range. Similar bimodal feeding patterns were noted by Squires (1973, 1974) and Lynch (1974) for domestic sheep and by Gonzalez (1964) and Smith (1959) for cattle. Bowns (1971), working with unherded sheep on lower and drier mountain range in southern Utah, recorded a bimodal pattern and earlier afternoon feeding similar to that of the unherded sheep on foothill pastures in this study. Hunter (1954) observed an additional midday feeding period for unherded sheep on Scottish hill pastures, similar to that reported for wild desert bighorn sheep in Utah by Wilson (1968). Honess and Frost (1942) and Spencer (1943) noted frequent interruptions of feeding for rumination with less of a bimodal pattern for bighorn sheep. Hoefs (1974) indicated that Dall bighorn sheep fed twice daily during the short days of winter near the Arctic Circle in Canada but included a midday feeding period at other times of the year.

Daily elevation changes

On steep mountain range and the gently sloping foothill pastures the sheep moved downhill while feeding each morning and in the afternoon moved uphill while feeding. Nightly bedgrounds were located on the higher ground, and midday ruminating and idling sites were generally at lower elevations. On successive nights the bedgrounds were usually farther uphill along the crest of a ridge and were not used more than two successive nights on mountain range. The sheep studied by Bowns (1971), however, repeatedly utilized the same bedgrounds at night. Since his sheep reached the bedground before nightfall and the cessation of feeding, those ridges were overgrazed. By contrast, the midday resting areas were used repeatedly by sheep in my study until another favorable site was encountered farther up the canyon bottom as the sheep each day grazed an area farther up the side of a ridge. Most traveling without feeding on mountain range occurred at the end of a feeding period as the sheep trailed to either a night or midday resting area. Hunter (1954) noted a similar daily uphill and downhill movement among sheep on hill pastures in Scotland as did Bowns (1971) for unherded sheep in southern Utah. Wilson (1968) noted analagous downhill and uphill daily movement of desert bighorn sheep in southeastern Utah. Hunter (1954) observed a reversal of this summer movement pattern in the winter months during which the sheep occupied the higher ground during the day.

Bowns (1971) suggested that any fencing in such mountainous terrain be done along the crests of ridges to reduce the overuse of the crests and to keep the flock within a single watershed.

Synchrony of activity

The sheep engaged in identical activities synchronously. Such flock activity often has been stated for sheep, but data to support the observation have been lacking. In my investigation data were collected from the scan sampling of sheep behavior at periodic instants as suggested by Altmann (1974). The four individuals observed at each scan were more often found in the same activity than would have been observed had their activities been randomly chosen. Scott (1945, 1956, and 1960) and Hafez and Scott (1962) wrote of the social organization of sheep and their great development of allelomimetic behavior. They indicated that such behavior was a result of early mother-young and young-young social learning. Arnold and Pahl (1974) studied the mixing of two flocks of different breeds and found that the sheep sought the company of their own breed but were not concerned with particular individuals. The two flocks fully integrated in 20 to 22 days. Bowns (1971) observed one group pass through another group of a separate breed while feeding without becoming mixed. My data leave open the possibility that synchronous activity could be caused by simultaneous response to internal or external factors. Dudzinski, Pahl and Arnold (1969) noted that sheep have a basic individual distance which they deliberately maintain. Feeding or traveling by one sheep might cause its herdmates to join in the activity simply to stay together. Probably a few individuals respond to these internal and external stimuli while many of the sheep may primarily join any new activity to remain with the flock.

Daily movement

No attempt was made to monitor distances traveled by individual sheep. I recorded only the flock movement by utilizing a topographic map to estimate both horizontal and vertical distances. At both the foothill and mountain locations the flock tended to maximize vertical travel within the limits of topography and daily movement. On foothill pastures the flock's daily vertical travel was limited by the small differences in elevation within each pasture. In contrast, on mountain range the flock could and did choose high nightly bedgrounds and low midday rest areas as much as 300 m different in elevation. During most of the season on mountain range the flock ascended farther uphill in the afternoons than they descended in the morning so that the flock occupied higher parts of the mountain slopes on succeeding days.

The average daily horizontal movement of sheep at the two locations was about 2100 m. Individual sheep certainly walked and fed over greater horizontal distances than this. If one assumes that on the average individual sheep traveled on paths which were at 45 degree angles to the line of movement of the flock, then individual sheep would have covered 1.4 times the general flock distances. On this basis individual sheep were estimated to have traveled 2980 m and 2910 m on mountain and foothill range, respectively. These distances are much less than those recorded for sheep in most other studies (Cory 1927, Bowns 1971, Squires 1973, 1974). Cresswell and Harris (1959) reported similar distances traveled by Rambouillet ewes on 1-2 ha pastures in Utah. On my study areas,forage and water were readily available as was shade except for certain seeded foothill pastures. Consequently the sheep did not need to move far to obtain daily amenities. Range managers must recognize that both the distribution and quantity as well as the presence or absence of animal requirements are important.

## Time and Energy Budgets

To apply knowledge of sheep behavior to grazing management for improved production the range manager needs not only to understand the responses of sheep to changes in the habitat but must also understand the effects of management upon the efficiency of energy harvest and conversion to useable products. Rushing (1973) suggested that once the daily time budget of homeotherms can be predicted throughout the year, the daily energy expenditures can be calculated by adding the metabolic costs of separate activities. Thus following the lead of Cook (1970) and Osuji (1974), the daily time budgets of the sheep in my investigation were projected to daily energy expenditures based on estimates of metabolic costs of each activity. This should help clarify the additional energy expenditures of sheep grazing on rangeland compared with housed sheep which have been the subject of many studies providing energy data.

### Assumptions

Time budgets were taken from Table 33 for the 15-hour day of my study at the foothill and mountain locations. Energy expenditure for resting metabolism was based on the data of Blaxter (1967) for 4-6 year old ewes. All expenditures were calculated for 60 kg ewes, a typical size for range ewes in Utah. Data for energy costs associated with ruminating, standing compared with lying, and the cost of feeding were based on the work of Graham (1964). Energy costs for walking were based on distances estimated in this study combined with the energy expenditure data of Corbett, Leng, and Young (1969) for variable speed walking characteristic of movement while feeding. Like Cook (1970) I assumed the cost of walking downhill was the same as that on level ground, so vertical movement expenditures were added only for the daily uphill climb.

Projections

Ewes grazing foothill range in May and June at Tintic expended an estimated 1554 kcal per 15-hour day for resting metabolism and specified activities (Table 36). The three principal components included 747 kcal for body maintenance, 395 kcal for feeding and ruminating, and 412 kcal for standing and walking. Within the 15-hour day studied, energy expenditures for activities exceeded the cost for resting metabolism.

Similar projections for ewes grazing on mountain range indicated energy expenditure during a 15-hour day of 1587 kcal for resting metabolism and activities, slightly more than on the foothill situation. On mountain range the ewes spent less energy, 343 kcal, for feeding and ruminating due to the shorter feeding time there. As a result of the large vertical climb daily the sheep on mountain range spent more energy, 497 kcal, standing and walking than they did on foothill pastures. The estimated energy expenditure for resting metabolism and activity for just the 15-hour day approached the 24-hour estimates for a grazing sheep as calculated by Osuji (1974).

Further projection of my estimates to the 24-hour day plus production functions may be helpful for comparison with other research for

Table 36. Time and estimated energy budgets for 60 kg ewe on range during 15-hour day of the study.

| Source | Foothill range | | Mountain range | |
|---|---|---|---|---|
| | Units | Cost | Units | Cost |
| | hr | kcal | hr | kcal |
| Resting metabolism[a] | 15.0 | 747 | 15.0 | 747 |
| Ruminating[b] | 4.2 | 60 | 5.2 | 78 |
| Standing[b] | 14.1 | 287 | 12.8 | 262 |
| Feeding[b] | 10.3 | 335 | 8.2 | 265 |
| | | 1429 | | 1352 |
| Movement[c] | m | | m | |
| Horizontal | 2910 | 115 | 2980 | 118 |
| Vertical | 22 | 10 | 248 | 117 |
| Movement | | 125 | | 235 |
| Daytime maintenance and activity | | 1554 | | 1587 |

[a] Blaxter 1967 (55.4 kcal/kg $W^{.75}$/24 hr for 4-6 yr old ewes)

[b] Graham 1964 (0.24 kcal/kg/hr - energy above resting metabolism to ruminate, 0.34 kcal/kg/hr - energy above resting metabolism to stand, 0.54 kcal/kg/hr - energy above resting metabolism and standing to feed)

[c] Corbett, Leng, and Young 1969 (0.00066 kcal/kg/m for horizontal movement, 0.00788 kcal/kg/m for vertical climb - energy above resting metabolism, standing, and feeding to traval about range

Table 37. Extension of time and energy budgets for 60 kg ewe on range to 24-hour day and production functions.

| Source | Foothill range Units | Foothill range Cost | Mountain range Units | Mountain range Cost |
|---|---|---|---|---|
| | hr | kcal | hr | kcal |
| Daytime maintenance and activity[a] | | 1554 | | 1587 |
| Nighttime projections | | | | |
| Resting metabolism[b] | 9.0 | 448 | 9.0 | 448 |
| Ruminating[c] (half time) | 4.5 | 65 | 4.5 | 65 |
| Standing[c,d] | 5.2 | 107 | 5.2 | 107 |
| Nighttime | | 620 | | 620 |
| Daily maintenance and activity | | 2174 | | 2207 |
| Production functions | | | | |
| Ewe daily gains[e] | | 58 | | 58 |
| Wool growth[e] | | 50 | | 50 |
| Milk for lamb[f] | | 1058 | | 490 |
| Production | | 1166 | | 598 |
| Total daily energy expendicture | | 3340 | | 2805 |

[a] From Table 36; [b] Blaxter 1967; [c] Graham 1964; [d] Ruckebush 1972; [e] Cook 1970 and my gain data from Table 34; [f] From Table 38.

Table 38. Estimated energy expenditure by the lamb and that energy obtained from the ewe on range.

| Source | Foothill range | | Mountain range | |
|---|---|---|---|---|
| | Units | Cost | Units | Cost |
| | hr | kcal | hr | kcal |
| Resting metabolism[a,b] | 24.0 | 515 | 24.0 | 632 |
| Ruminating[c] | 2.175 | 5 | 7.275 | 37 |
| Standing[c] | 19.3 | 66 | 18.0 | 129 |
| Feeding[c] | 2.575 | 14 | 6.15 | 70 |
| | | 600 | | 868 |
| Movement[d] | | | | |
| Horizontal | 2910 m | 19 | 2980 m | 41 |
| Vertical | 22 m | 2 | 248 m | 41 |
| Lamb maintenance and activity | | 621 | | 950 |
| Lamb gain including wool[a,e] | | 465 | | 559 |
| Total lamb energy expenditure | | 1086 | | 1509 |
| Lamb energy from milk[f] | | 814 | | 377 |
| Energy cost to ewe for milk[g] | | 1058 | | 490 |

[a] Chiou and Jordan 1973, 10 kg lamb @ 91.5 kcal/kg $W^{.75}$ on foothill;

[b] Rattray et al 1973b, 21 kg lamb @ 64.4 kcal/kg $W^{.75}$ on mountain;

[c] Graham 1964, energy above other activity, same hours as ewe each location for standing, 0.25 of ewe hours on foothill and 0.75 of ewe hours on mountain for ruminating and the reverse relationship for feeding time;

[d] Corbett, Leng, and Young 1969, same distances as ewes each location;

[e] Rattray et al 1973a, 212 g/day gain on foothill and 148 g/day gain on mountain range;

[f] Assuming one lamb per ewe, 0.75 of lamb expenditure on foothill and 0.25 of lamb expenditure on mountain range;

[g] Gardner, Hogue, and Bensadoun 1964, 0.77 efficiency for lamb needs.

management considerations. To extend the data to the 24-hour day I assumed the sheep did not feed, ruminated half the additional 9 hours, and stood 5.25 hours (Ruckebush 1972). Under these assumptions the estimated 9-hour energy expenditure was 620 kcal for each location (Table 37). Based on the gains of ewes in this study and the energy costs suggested by Cook (1970), additional energy expenditures included 50 kcal daily for wool production and 58 kcal for ewe daily non-wool gain. Thus the 24-hour sheep energy expenditures, excluding lactation, were estimated to be 2282 kcal on foothill range and 2315 kcal on mountain range.

To estimate energy expenditures for lactation to support the lambs, 75% of the estimated lamb energy costs on foothill range and 25% of the estimated lamb energy requirements on mountain range were attributed to milk production by the ewes (Table 38). Expenditures by the ewe for milk production (Table 37) were estimated to be 1058 kcal on foothill range and 490 kcal daily on mountain range based on only one lamb per ewe (Gardner, Hogue, and Bensadoun 1964; Chiou and Jordan 1973). Therefore, with most of the maintenance, activity, and production costs accounted for, the sheep on foothill range were estimated to have expended 3340 kcal of energy daily but only 2805 kcal daily while grazing mountain range.

Relation to performance

Daily feeding time of the sheep on mountain and foothill range was proportional to the energy estimated to have been expended for maintenance, activity, and production at each location. The feeding time ratio, 490/620 minutes, for the two locations and the estimated energy expenditure ratio, 2805/3340 kcal, were nearly identical, with one minute of feeding for about each 5.5 kcal of energy expended. The increased feeding time on foothill range could have been related to the increased lactation energy demands while the sheep were at that location. These energy budget projections suggest a linear relationship between time spent feeding and amount of intake or useful energy consumed. Arnold and Birrell (1977) suggested that increasing demands for higher intakes could be achieved by increases in either time spent feeding or by increased rate of intake while feeding. Arnold and Dudzinski (1978) noted that there is no set pattern of adjustment in time of feeding, size of bite, or rate of biting while feeding, but they reported that sheep with different energy demands are able to maintain these related intake differences over a wide range of pasture conditions.

## Management

Activities of sheep and management practices which are wasteful of energy reduce the efficiency of livestock production on rangelands. To improve range livestock performance the manager needs to reduce those sheep activities which are least essential or those which are most energy expensive, feeding time and vertical travel for example, without reducing forage intake or upsetting productive patterns of behavior. It might prove helpful to find ways of reducing feeding time while at the same time increasing the rate of intake or energy harvest while feeding since the energy cost of feeding is proportional to the time spent feeding and not to the rate of intake or to total daily intake. Then the sheep could spend more time ruminating, which is less energy expensive but serves a productive function.

Management solutions may vary among managers and areas grazed. Perhaps the wise use of fencing or better herding techniques could reduce the vertical distances between midday resting areas and nightly bedgrounds. Sheep feeding across slopes nearer the contour and walking less to bedding areas after morning and afternoon feeding would waste less energy.

Early afternoon feeding such as occurred on foothill pastures in this study did not appear very intensive and may have produced a low rate of intake. Nevertheless, such additional feeding and intake may be necessary for the level of lactation required for adequate lamb performance. Any feeding that exceeded about 20 g/hr intake of typical forages would harvest more energy than would be used in the act of feeding. On forages with about 50% digestibility feeding must achieve more than about 75 g/hr intake on a long term basis to harvest any energy beyond the needs of the ewe for maintenance and activity under range situations similar to those in this study and common to western United States rangelands.

## Summary

The range sheep industry, economically important to Utah and to the United States, produces needed food and fiber from much of the less productive land. Improved management will depend upon more knowledge of the range ecosystem. Research to determine the time spent by sheep in activities of differing energy demands and to determine what factors affect sheep activity time allocation was completed in 1965 and 1966 in central Utah.

The research was conducted on spring foothill range near Eureka and on summer mountain range near Scofield, both in central Utah. Rambouillet sheep were loosely herded on the sagebrush-aspen areas on mountain range and were unherded on foothill range where the sheep were assigned to 14 pastures either 25 ha or 125 ha in size. Activities of sheep were studied in May and June at two grazing intensities on three species of seeded wheatgrasses and on native sagebrush-juniper range. Feeding, standing ruminating, lying ruminating, standing idle, lying idle, and traveling were recorded as all-inclusive activities by observing the behavior of four randomly selected sheep from among marked ewes at 90 instantaneous scans at 10-minute intervals from 0500 to 1950 hours on each of 28 days at each location. Hourly readings were made on the degree of cloudiness, wind movement, ambient temperature, and relative humidity.

Data were analyzed to determine components of variance and to evaluate effects of month, grazing intensity, and kind of forage. Each activity was regressed on environmental factors in a stepwise-deletion multiple regression procedure.

The foothill data were analyzed first as seven treatments with identification of variation due to two replications and two months and, secondly, without the native foothill range as a 2-month, 2-intensity, 3-species factorial design with two replications.

Sheep daily repeated a bimodal routine of early morning feeding followed by midday rumination and rest which lasted until late afternoon, followed by feeding again before bedding down at nightfall on high ground. On mountain range the morning and afternoon feeding periods were of similar length, but on foothill range the sheep began feeding earlier in the afternoon and thus fed longer in the afternoon than during the morning hours. Sheep were highly synchronous in their choice of activities.

Each null hypothesis formulated for testing in the study was considered in light of the data collected and either accepted or rejected separately for each activity. These decisions are summarized in Table 39. Study design prevented determination of causes of some of the differences noted in sheep activities.

Sheep spent more time feeding on seeded foothill range than on either native foothill or mountain range. Conversely, they spent more time lying ruminating and standing idle during the daylight hours studied on mountain and on native foothill ranges. Traveling time was greater on mountain than on foothill range, but the horizontal distances traveled were the same at both locations. Sheep spent more time lying idle on native foothill range than on seeded pastures. At the spring foothill location the sheep also spent more time standing idle and traveling in May than in June. No differences were noted in any activities between intensities of grazing.

Both lying ruminating and lying idle showed positive regressions on relative humidity. The daily feeding of sheep responded positively to average daily temperature. Traveling and standing idle were negatively related to mean daily temperature, which averaged 20 C and varied only within a narrow range during the two periods of study.

All regressions of weather factors, though significant on one or more factors for all activities except standing ruminating, were of little predictive value since coefficients of multiple determination were low for all regression models.

Table 39. Summary of null hypotheses and decisions resulting from the study of sheep activities.

| | |
|---|---|
| Hypothesis A. | Sheep spend the same amount of time in specified activities on both foothill and mountain range.<br>- Rejected for each activity except Standing Ruminating. |
| Hypothesis B. | Sheep spend the same amount of time in specified activities on native and seeded foothill range.<br>- Rejected for each activity except Standing Ruminating and Traveling. |
| Hypothesis C. | Sheep spend the same amount of time in specified activities on three seeded wheatgrasses.<br>- Accepted for each activity. |
| Hypothesis D. | Stocking rate has no effect on sheep activity budgets on foothill range.<br>- Accepted for each activity. |
| Hypothesis E. | Changes encountered in environmental factors do not affect sheep activity budgets.<br>- Accepted for each activity and factor. |

Results were compared with other data reported in the research literature. Sheep activities necessary to the animal on a daily basis were little affected by small changes in the range environment. Feeding time was proportional to the estimated energy expenditure for maintenance, activity, and production at each location.

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