



Daily and seasonal activity patterns of the pika in southwestern Montana
by Robin Lee Kistler Moore

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

Montana State University

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Abstract:

Diurnal and nocturnal activity patterns of pikas were studied by visual observations and radio telemetry during summer and fall 1984 and winter 1985, in Gallatin Canyon, Montana. Inferences were made on the extent of meadow feeding and haypile feeding during the winter, and seasonal changes in behavioral patterns were related to winter survival strategies. Pika body temperature and ambient temperature were recorded during the fall. Total pika activity was significantly greater in fall than during winter; however, there were no significant differences between summer-fall and summer-winter activity. There were no significant differences in mean proportion of activity throughout the 24-hour periods, although pikas showed small, consistent peaks of activity during the morning and late afternoon in all seasons. There was no significant correlation between pika activity and ambient temperature or between pika body temperature and ambient temperature. Throughout the seasons, pikas spent a major portion of their time inactive below the talus surface and feeding above the surface. The proportion of time spent meadow feeding did not vary significantly throughout the seasons. More time was spent in haypiling, perching, and social behavior during summer than fall. The proportion of time spent feeding and inactive below the surface varied significantly with time of day during summer and fall but not in winter. During periods of inclement weather in the fall, nocturnal meadow feeding was significantly reduced. During winter nights with temperatures below 17° C, there was a decrease in meadow foraging excursions and an increase in haypile utilization, but these differences were not significant.

The amount of nighttime activity did not vary significantly between seasons and consisted primarily of meadow feeding. Moon phase did not have any measurable effect on the amount of nocturnal pika activity throughout the seasons. During the winter the greatest amount of time was spent inactive below the surface. The intensity of activity was less than in summer and was confined primarily to meadow foraging and activity near the haypile (haypile feeding).

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A thesis submitted in partial fulfillment
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of

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APPROVAL

of a thesis submitted by

Robin Lee Kistler Moore

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Diurnal and nocturnal activity patterns of pikas were studied by visual observations and radiotelemetry during summer and fall 1984 and winter 1985, in Gallatin Canyon, Montana. Inferences were made on the extent of meadow feeding and haypile feeding during the winter, and seasonal changes in behavioral patterns were related to winter survival strategies. Pika body temperature and ambient temperature were recorded during the fall. Total pika activity was significantly greater in fall than during winter; however, there were no significant differences between summer-fall and summer-winter activity. There were no significant differences in mean proportion of activity throughout the 24-hour periods, although pikas showed small, consistent peaks of activity during the morning and late afternoon in all seasons. There was no significant correlation between pika activity and ambient temperature or between pika body temperature and ambient temperature. Throughout the seasons, pikas spent a major portion of their time inactive below the talus surface and feeding above the surface. The proportion of time spent meadow feeding did not vary significantly throughout the seasons. More time was spent in haypiling, perching, and social behavior during summer than fall. The proportion of time spent feeding and inactive below the surface varied significantly with time of day during summer and fall but not in winter. During periods of inclement weather in the fall, nocturnal meadow feeding was significantly reduced. During winter nights with temperatures below -17°C , there was a decrease in meadow foraging excursions and an increase in haypile utilization, but these differences were not significant. The amount of nighttime activity did not vary significantly between seasons and consisted primarily of meadow feeding. Moon phase did not have any measurable effect on the amount of nocturnal pika activity throughout the seasons. During the winter the greatest amount of time was spent inactive below the surface. The intensity of activity was less than in summer and was confined primarily to meadow foraging and activity near the haypile (haypile feeding).

INTRODUCTION

Pikas are small lagomorphs found in Eurasia and western North America. The North American pika, Ochotona princeps, is limited to talus slopes and rockslides in boreal and alpine areas throughout the Sierra Nevada-Cascade and Rocky Mountain chains. They are herbivorous and feed on vegetation in meadows adjacent to rockslides. Like other lagomorphs, pikas are coprophagous and produce two types of feces, one of which is reingested (Severaid 1955, Johnson and Maxell 1966). Pikas have a low-energy diet of leaves and stems, and they do not easily accumulate fat. They do not switch to higher energy food items (seeds, fruits, insects) in late summer as do some hibernating small mammals such as ground squirrels (Iverson and Turner 1972, Hansen and Johnson 1976, Zegers and Williams 1977, Michener 1979, Jones, Jr. et al. 1983). Pikas do not hibernate but maintain high body temperatures and remain active all year (Krear 1965, MacArthur and Wang 1973, Markham and Whicker 1973). Because pikas must depend on adequate year-round food supplies, winter is a critical period, and pika behavior and physiology must be adapted to their need to feed frequently.

Pikas devote a significant portion of their time to hay gathering and are selective in the plants they gather relative to availability (Johnson and Maxell 1966, Millar and Zwickel 1972a, Elliot 1980, West 1980). They also maintain territories centered around their haypiles (Broadbooks 1965, Krear 1965, Kawamichi 1976). The haypiles are used during winter; however, most pikas do not store enough hay to serve as an exclusive winter food source (Hayward 1952, Millar and Zwickel 1972a). It is assumed that pikas must forage to some extent beneath the snow during winter. Millar and Zwickel (1972a) and Conner (1983) inferred that haypiles serve as supplemental food supplies during harsh weather that would inhibit active foraging. More information is needed to clarify the significance of haypiling behavior (Millar and Zwickel 1972a, Smith 1981).

Pikas are easily observed when they are active on the rock surface during the day. Considerable information on their natural history is available (Severaid 1955, Krear 1965, Broadbooks 1965), and a few studies have quantified their activity patterns (Barash 1973, Smith 1974b, Conner 1983). Most studies of pika activity have been limited to observations of pikas active on the rockslide surface. However, their rockslide habitat provides excellent cover and restricts visual observations of activity when the pikas

are below the rock surface. Snow cover further inhibits visual observations.

Summer and fall studies have shown that pikas feed actively during the day (Hayward 1952, Severaid 1955, Broadbooks 1965, Krear 1965). Anecdotal reports of nocturnal feeding activity (Severaid 1955, Smith 1974b) and calling (Dalquest 1948, Krear 1955, Smith 1974b) have been made, but little other evidence of night activity has been reported.

No quantitative observations have been made of pika subnivian activity, although a few observations of pika winter activity have been reported. Kawamichi (1968) observed that the Himalayan pika, Ochotona roylei, had very small haypiles and maintained activity both on the surface and in complicated burrow systems in the snow. The Japanese pika, Ochotona hyperborea, constructed large haypiles, and winter activities were confined beneath the snow cover (Kawamichi 1969). Markham and Whicker (1973) reported that pikas remained active all winter and tunneled extensively beneath the snow in colonies maintained in enclosures near Fort Collins, Colorado. Conner (1983) conducted one of the few field studies of pika winter activity, but he was limited to visual observations of pikas active on windswept talus surfaces.

This study utilized radiotelemetry to expand observations of pika activity to include nocturnal and

winter periods. The objectives of this study were:

- (1) To provide quantitative information on diurnal and nocturnal activity patterns of pikas during summer, fall, and winter;
- (2) To examine daily and seasonal variation in the duration of time spent in various activities (feeding, haying, investigation, social behavior, perching, and activity below surface);
- (3) To draw inferences from these observations on the extent of meadow feeding and haypile feeding during the winter;
- (4) To relate seasonal changes in behavioral patterns to winter survival strategies.

Data were also gathered on the relationship of pika body temperature to ambient temperature in the fall and the influence of weather on nocturnal activity patterns.

To fulfill these objectives, pikas were radio collared during summer and fall 1984, and winter 1985, at two sites in the lower Gallatin Canyon, Gallatin County, Montana. Quantitative data on activity, including activity during the night and under rock or snow cover, was gathered by systematic monitoring throughout 24-hour periods. Radio transmitters designed to measure body temperature were implanted in animals and monitored during the fall.

SITE DESCRIPTION

Populations of pikas were studied at two sites in the lower Gallatin Canyon approximately 40 and 48 kilometers (km) south of Bozeman, Gallatin County, Montana (Figure 1). The sites were at an elevation of 1,707 meters (m) and were located near the Cascade Creek and Greek Creek drainages. These sites were chosen because they afforded easy access for gathering winter data.

The lower section of the Gallatin Canyon from the Big Sky Ski Resort northward is quite narrow and typical of an unglaciated stream-cut canyon. In this northern section of the canyon, the Gallatin River has cut into Precambrian basement rocks which account for essentially all of the exposed outcrops, including the talus slides at both study sites. These loose, large, angular rocks are primarily banded gneisses containing black or dark-green amphibole bands and pink bands of quartz, feldspar, and silica-rich minerals. These talus rocks are often cut by thin black diabase dikes containing mainly pyroxene, plagioclase, and white pegmatite veins (McMannis and Chadwick 1964, Fritz 1985).

The following climatological data were recorded at a National Oceanic and Atmospheric Administration (NOAA)

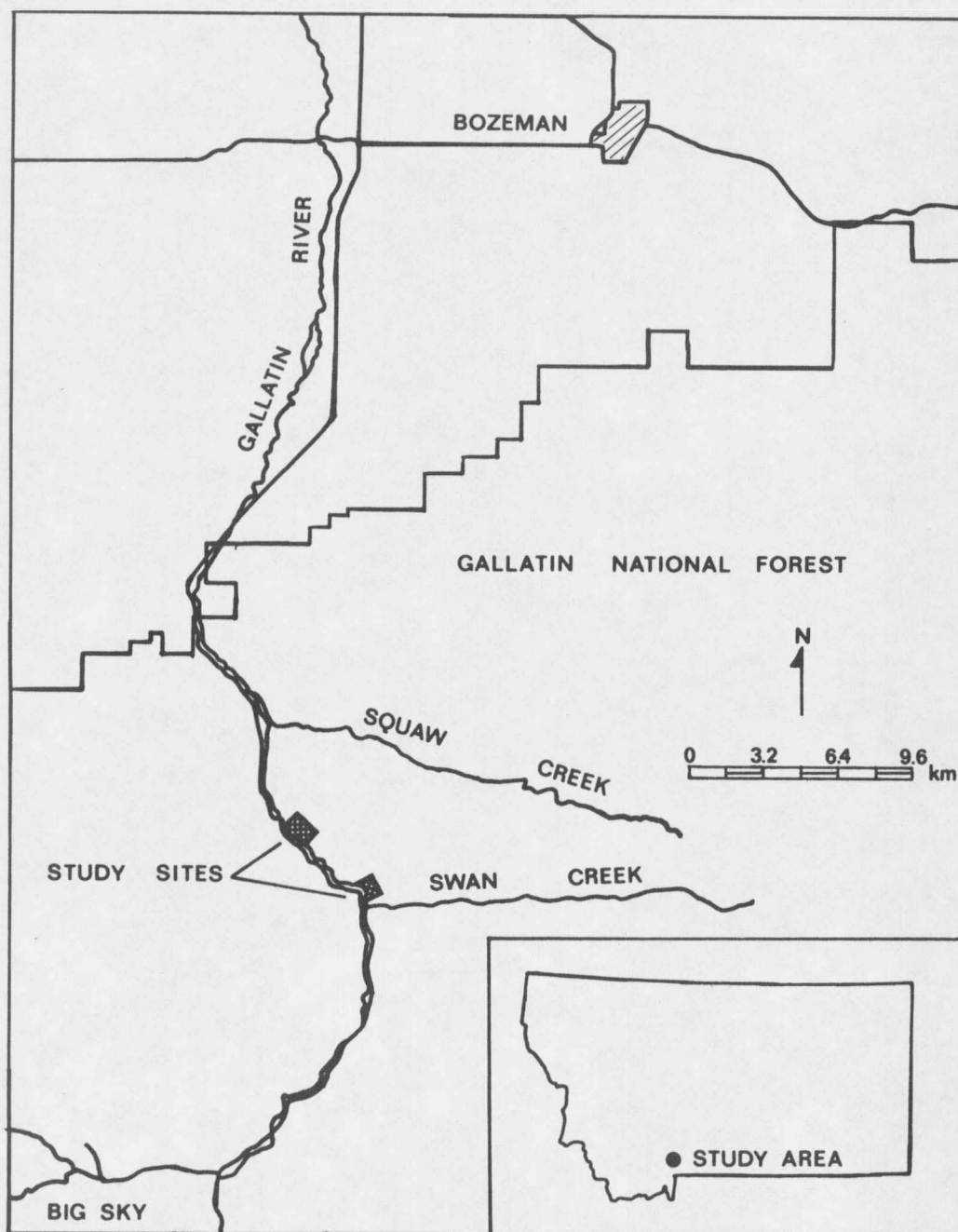


FIGURE 1. Map of study area.

reporting station south of the study site near Big Sky at an elevation of 2,012 m. During August 1984, temperatures ranged from -1.1°C to 29.4°C with a mean temperature of 14.5°C . Total precipitation was 10.3 centimeters (cm). In the fall (September and October 1984), temperatures ranged from -15 to 26.7°C with a mean temperature of 4.7°C . Monthly precipitation averaged 5.3 cm with a maximum snow depth of 20.3 cm by the end of October. During January and February 1985, temperatures ranged between -37.2°C and 8.3°C with a mean temperature of -9.4°C . Monthly precipitation averaged 2.4 cm with a maximum snow depth of 66 cm by the end of February. During these winter months, the rockslide and meadow maintained a complete snow cover with only the largest rock crevices remaining open.

Vegetational characteristics at both study sites are similar. Both rockslides have primarily western exposures and are at the base of steep slopes with adjacent rocky cliffs. The surrounding area is forested with a mixture of Douglas fir (Pseudotsuga menziesii) and lodgepole pine (Pinus contorta). The understory contains Rocky Mountain maple (Acer glabrum), chokecherry (Prunus virginiana), and ninebark (Physocarpus malvaceus). Open areas at the base of the rockslides contain a variety of grasses, forbs, and shrubs. Dominant plants which were eaten by pikas include red raspberry (Rubus idaeus), currant and gooseberry (Ribes

spp.), wild rose (Rosa sp.), alder (Alnus sp.), thimbleberry (Rubus parviflorus), yarrow (Achillea millefolium), goldenrod (Solidago sp.), yellow clover (Melilotus officinalis), fireweed (Epilobium angustifolium), and sagebrush (Artemisia sp.), as well as a variety of grasses (Poa, Stipa, Agropyron, Phleum, Elymus, and Agrostis).

METHODS

Trapping and Radiotelemetry Techniques

In July and August 1984, five adult pikas (four females and one male) were trapped with Havahart live traps (46 by 13 by 13 cm) baited with fresh vegetation. Fresh willow (Salix sp.) was the most successful bait. Traps were set near haypiles and along commonly used routes to adjacent feeding areas. Traps were checked once or twice each day as exposure to the midday sun was stressful to the pikas. Upon capture, pikas were transported back to the lab and maintained in a metal mesh holding cage (41 by 25 by 30 cm). The cage contained a 30-cm black cardboard mailing tube for shelter. The animal was provided with fresh damp vegetation, apple, and a small dish of water. The pikas were held for a maximum of 8-24 hours before being returned to the study site.

For handling, pikas were placed in a denim sack with a zipper at one end and drawstring at the other. They were sedated with an intraperitoneal injection of Nembutal (18.5 milligrams/kilogram) which was 26.4% of the dosage used by MacArthur and Wang (1973). The pikas were weighed, sexed (Duke 1951), and marked with colored metal ear tags. Four

of the pikas were equipped with radio collars containing SM-1 transmitters (AVM Instrument Company, Ltd.) and mercury (Hg)-625 batteries encased in acrylic. Radios weighed 8-9 grams (g) each. A Telemetry Systems RT-20A receiver with a three element hand-held Yagi antenna was used to monitor radio signals. These four animals were followed from August through early November. Three animals lost their collars, and two of these collars were replaced during this 4-month interval. By early November all radio collars had been lost.

Animals were retrapped and equipped with new collars in order to complete winter observations. Two pikas were trapped during the first week of January 1985. Alfalfa hay was used for bait and seemed to be readily taken by the pikas. One pika had been radio collared previously, and the other pika had been used earlier for a body temperature transmitter implant experiment. One of these lost its collar in mid-January. The other pika was followed through February when it subsequently lost its collar.

Activity Observations

Activity and location of the radio collared animals were monitored during the summer (28 July - 16 September) and fall (17 September - 26 October) of 1984 and the winter (9 January - 9 February) of 1985. The designation of the

summer and fall seasons was based on a distinct decrease in the haypiling behavior of the pikas in September. A complete record of activity, as determined from radio signals and visual observations, was recorded on a portable cassette tape recorder. Four 6-hour sampling periods were used each week to cover a complete 24 hours. This schedule was followed for summer and half of fall. Because of extremely cold temperatures in mid-October, January, and February, sampling periods were reduced to 3 hours each. The specific animal sampled was selected according to a predetermined schedule that daily rotated the order in which the four animals were used. The schedule was adjusted as animals lost radio collars throughout the study. The 6-hour and 3-hour observation periods were stratified into 30-minute sampling periods for statistical analysis.

By combining visual observations with radiotelemetry during summer and fall, the type of activity, as well as total activity time, was monitored. Activity below the surface and inactivity below the surface were also recorded based on variation in the radio signal. The time spent in each activity was expressed as a percentage of the 30-minute sampling period. For analysis of daily activity patterns, each 24-hour period was divided into four periods. The morning period began 1 hour before sunrise and continued for a total of 4 hours; midday encompassed 4 hours from

1100-1500 h. The late afternoon 4-hour period began 3 hours before sunset and continued 1 hour after sunset. The night period included 6 hours from 2200-0400 h for a total of 20 hours per day. The activity types are classified below.

Feeding

This foraging behavior included movement to adjacent meadows or to vegetated areas within the rockslide and consumption of the plant material gathered there. The vegetation was usually clipped at the base and then eaten without use of the forepaws. A feeding pika generally maintained a horizontal alert posture with tarsi resting on the ground (Barash 1973). During late fall, pikas were frequently observed feeding on lichens growing on the rock surface. This was also included as feeding behavior. In the winter, determination of meadow feeding activity was based on radiotelemetry locations in known feeding areas away from the haypile. Haypile feeding activity was estimated based on the total time an animal spent active in the vicinity of its haypile. Haypile feeding was not observed during summer or fall.

Haypiling

Haying trips included movement to an adjacent meadow, gathering vegetation, and returning to the haypile where the

material was deposited. Animals usually climbed on a nearby rock, perched briefly (10-30 seconds) and uttered a short call before leaving on another haypiling trip (Broadbooks, 1965). Unlike feeding behavior, a haying animal usually maintained an alert upright posture on all four feet. Average length of haying trips (1.0 minute) was usually significantly shorter than feeding trips (Barash 1973, this study).

Investigation

This category included general locomotory behavior, investigation or exploration of territories, and investigation or rearrangement of haypile material.

Social Behavior

This territorial behavior included aggressive social interactions between two or more pikas. Aggressive behavior was the main factor in the maintenance of territories and social spacing (Svendsen 1979). Chasing of intruders, vocalizations before and after chasing, and vocalizations between pikas with adjacent territories were the most common forms of aggressive behavior noted.

Perching

Perching was recorded when a pika remained seated on a rock in the rockslide. In addition to remaining motionless or resting on a rock, pikas could also perform other activities, such as sunning, cheek rubbing, short grooming movements, coprophagy, and calling without apparent interactions with other pikas. These additional activities were included as perching time and not analyzed separately. A pika had to remain perched on the same rock for a minimum of 5 seconds for perching behavior to be recorded.

Activity Below Surface

This included all activity when the animal was beneath the rock surface or the snow and was determined by variation in the volume and pattern of the radio signal. During winter, meadow feeding and haypile feeding were not included in activity below the surface.

Activity and Ambient Temperature

Beginning in late September through February, air temperature (Taylor Instruments thermometer) was recorded during each observation period. In January and February, temperature readings beneath the rocks and snow were obtained during each observation period by using a Taylor

Instruments maximum-minimum thermometer suspended within the rocks below a radio-collared pika's haypile. In March through April, maximum-minimum air temperatures were recorded while a Taylor Instruments Temperature Recorder recorded temperatures beneath the snow and rocks. Field-recorded temperature data were supplemented with climatological data from a NOAA reporting station near Big Sky, Montana.

The mean percentage of activity per 30-minute period was calculated for morning, midday, late afternoon, and night for each 24-hour observation period during summer, fall, and winter. Activity percentages were compared with maximum or minimum ambient temperatures measured at the NOAA station on each observation date. Minimum ambient temperatures were correlated with morning and nighttime activity readings while maximum ambient temperatures were correlated with midday and late afternoon activity. On the average, the ambient temperatures recorded in the field were 0.5°C higher than the ambient temperatures recorded at the NOAA station near Big Sky.

Effect of Moon Phase and Weather on Nocturnal Activity

Nighttime activity data were grouped by moon phase (first quarter, full moon, last quarter, and new moon) for each season and analyzed for differences in mean percentage

activity per 30 minutes among the different moon phases. For this analysis, night data included all 30-minute samples from sunset to sunrise. When the nighttime observations did not coincide with the night of a particular moon phase, the data were assigned to the moon phase which occurred closest to the observation night. In no case did the data assigned to a specific moon phase differ from the peak of that phase by more than three nights.

The extent to which weather conditions influenced nocturnal activity, particularly feeding activity, was analyzed. For summer, meadow feeding activity for each nighttime observation period (2200-0400 h) was classified according to the following weather conditions: clear/cloudy (1 to 4°C) and overcast/raining. For fall, the weather classifications were clear/cloudy (-4 to 3°C) and rain/snow. During the winter, both meadow feeding and haypile feeding estimates for each nighttime observation period were grouped according to the following weather conditions: clear/bitter cold (-13 to -24°C), clear/cold (-12 to -7°C), and snowing or snow earlier in the day.

Body Temperature Monitoring

Body temperatures of pikas were monitored in the field during fall. Two pikas were trapped on 28 September and 12 October, and two Model T transmitters (Mini-Mitter Company,

Inc.) equipped with 850 milliampere-hour (mah) lithium batteries were implanted. The transmitter-battery package was coated with a Parafin/Elvax coating, and the entire unit weighed 13 g. A modified three channel walkie-talkie with a Beat Frequency Oscillator was used as a receiver.

The pikas were sedated with a slightly stronger dosage of Nembutal than those animals being radio collared. The fur along the lower back was clipped, and a 3.5 cm incision was made along the lower back above the hip. The transmitter was inserted between the skin and musculature in the flank area. The incision was closed with chromic gut absorbable sutures (4-0, 2.0 metric with cutting J-1 needle and 45 cm thread). Nolvasan solution was used as an antiseptic to clean the wound and tools. Pikas were held for observation for 6 hours and then returned to their haypile areas.

During the activity monitoring periods, body temperature readings of these two animals were recorded every 30 minutes. One pika kept the transmitter 12 days and the other animal retained it for 19 days. Both transmitter packages were lost through the original incisions. Both pikas lived, and one was later retrapped in January and radio collared.

Statistical Analyses

Statistical multiple group comparisons were made using one-way analysis of variance (ANOVA) and the Newman-Keuls test. Individual pair-wise comparisons were made using Student's t-test. A simple linear regression was used to test for correlations between daily seasonal activity and ambient temperature and between body temperature and ambient temperature. A significance level of $P < 0.05$ was used for all tests. Calculations and statistical tests were performed using the MSUSTAT Statistics Package (R. E. Lund, Montana State University, Copyright 1983).

RESULTS AND DISCUSSION

Seasonal Differences in Amount of Activity

An analysis of variance of the mean percentages of time active per 30-minute interval showed a significant difference between seasons ($P=0.017$). Total activity was significantly greater in the fall (55.5%, $n=192$) than during the winter (42.9%, $n=96$). However, there was no significant difference between summer (50.5%, $n=230$) and fall activity or summer and winter activity ($P>0.05$).

Seasonal Differences in Daily Activity Patterns

The mean percentages of time active per 30-minute interval for morning, midday, late afternoon, and night are shown in Table 1 for summer, fall, and winter. During the summer, the pikas showed small peaks in activity during the morning (57.9%) and late afternoon (62.0%); however, there was no significant difference ($P=0.084$) in mean proportion of activity among the four daily periods. In the fall, there were again morning (73.8%) and late afternoon (61.1%) activity peaks, but these did not differ significantly from midday activity (56.6%). Other authors have reported peak periods of activity during early morning and late afternoon

TABLE 1. The mean percentage of activity per 30-minute period for each time of day period during summer, fall, and winter.

Time of Day	^b $\bar{X}$ Percentage Activity (n)			^a ANOVA Results	
	Summer	Fall	Winter	F	P
Morning	<u>57.9</u> (37)	73.8 (32)	<u>49.4</u> (16)	3.172	0.046
Midday	<u>44.6</u> (37)	<u>56.6</u> (32)	<u>39.8</u> (16)	1.759	0.177
Late Afternoon	<u>62.0</u> (37)	<u>61.1</u> (31)	<u>52.1</u> (16)	0.478	0.627
Night	<u>48.8</u> (60)	<u>38.7</u> (48)	<u>40.3</u> (24)	1.151	0.320
*ANOVA Results					
F	2.243	7.419	0.416		
P	0.084	0.000**	0.746		

^a From ANOVA testing for heterogeneity among seasons.

^b Means sharing a common underline are not significantly different (Student-Newman-Keuls test; $P < 0.05$). Where an underline is discontinuous, the significance level for the difference between the two adjacent means is $P < 0.05$.

* From ANOVA testing for heterogeneity within each season.

** The mean percentage of nighttime activity during the fall was significantly less ($P < 0.05$) than the three daytime periods as shown by the Student-Newman-Keuls test.

in the summer and fall (Hayward 1952, Broadbooks 1965, Barash 1973, Smith 1974b).

During the winter, the rockslide maintained an almost complete snow cover. No pika activity was observed on the surface, although natural openings to the rocks and haypiles existed through late February. All activity was monitored using radiotelemetry. The pikas maintained small activity peaks during the morning (49.4%) and late afternoon (52.1%) periods; however, there was no significant difference ($P=0.746$) in the mean percentage of time active among the four daily periods.

A comparison between seasons of the mean percentage activity per 30-minute period for morning, midday, late afternoon, and night is also shown in Table 1. During the 4-hour morning period, the mean proportion of activity during the fall (73.8%) was significantly greater ($P=0.046$) than summer (57.9%) or winter (49.4%). There were no significant differences between seasons in the mean percentage activity for the midday, late afternoon, and night periods.

Seasonal Relationship of Activity and Ambient Temperature

Figure 2 presents graphs of mean percent activity per 30 minutes and ambient temperature. There was no significant linear correlation between mean proportion of

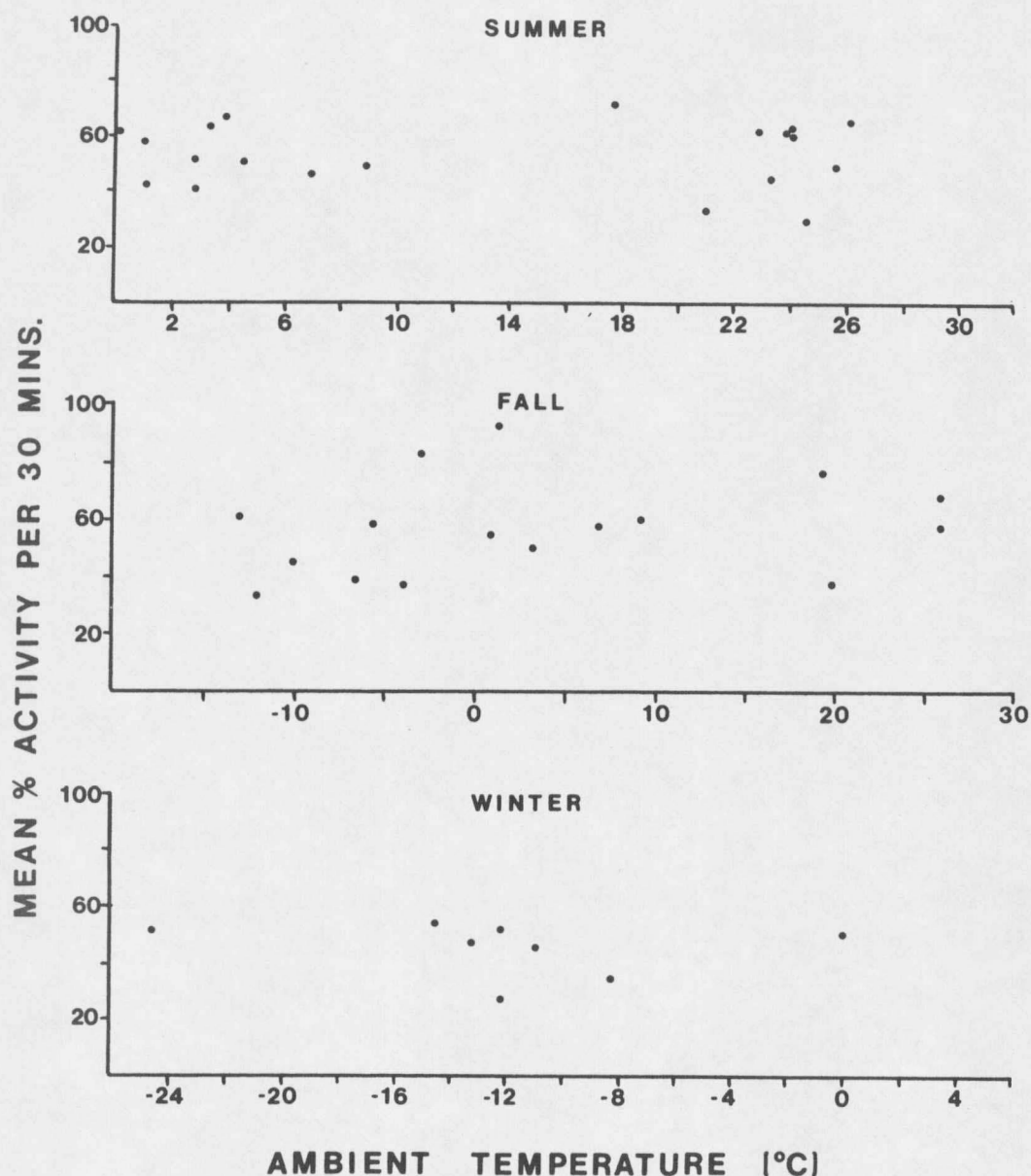


FIGURE 2. The mean percentage activity per 30-minute interval for morning, midday, late afternoon, and nighttime observation periods plotted against ambient temperature recorded during each period. Ambient temperatures for summer and fall were obtained from the NOAA Big Sky reporting station. Winter temperatures represent actual temperatures at the study sites.

activity and ambient temperature for summer ($r^2=0.0004$), fall ($r^2=0.066$), or winter ($r^2=0.043$). A simple regression calculated for the activity and temperature data combined from all seasons showed no linear relationship between activity and ambient temperature ($r^2=0.043$).

Smith (1974b) found a negative correlation between ambient temperature and activity of pikas during daylight in August and September at low altitude sites near Bodie, California, with highly reduced surface activity (5-10% surface activity) during the intense heat of midday. While I also found surface activity to be reduced at midday (39.8%) compared to morning (51.3%) and late afternoon (63.3%), radiotelemetry data indicated continued subsurface activity where temperatures remained cool. Total activity at midday was not significantly different in any season than activity during other daylight periods. My data corresponded more closely with Smith's high altitude site in which there was no correlation between diurnal activity and temperature during September.

Seasonal Variation in Different Activities

Differences in the mean percent time spent active between sunrise and sunset for seven different activities during summer and fall are presented in Table 2. Due to lack of visibility during the winter, only feeding, activity

TABLE 2. The mean percentage activity per 30-minute period for eight activities during summer, fall, and winter (daylight hours only).

Activity Type	^b $\bar{X}$ Percentage Activity (n)			^a Student's t-Test & ANOVA Results		
	Summer	Fall	Winter	F	P	t
Meadow Feeding	<u>21.6</u> (141)	<u>25.2</u> (102)	<u>16.8</u> (42)	1.559	0.210	
Haypile Feeding			11.4 (42)			
Haypiling	7.1 (141)	1.4 (102)			0.001	3.336
Social Behavior	1.0 (141)	0.3 (102)			0.010	2.580
Activity Below Surf.	<u>15.3</u> (141)	<u>28.2</u> (102)	<u>16.6</u> (42)	11.85	0.000	
Perching	12.0 (141)	5.0 (102)			0.0001	4.053
Inactivity Below Surf.	<u>33.9</u> (141)	<u>30.5</u> (102)	55.2 (42)	7.012	0.001	
Investigation	8.2 (141)	9.3 (102)			0.356	0.923

^a From ANOVA or Student's t-test for heterogeneity among seasons.

^b Means sharing a common underline are not significantly different by the Student-Newman-Keuls test where all three seasons are compared. Where an underline is discontinuous, the significance level for the difference between the two adjacent means is $P < 0.05$. For summer-fall comparisons the Student's t-test was used.

below surface (other than feeding), and inactivity below surface were recorded. Variation in the time spent in the different activity types among seasons showed that pikas spent a major proportion of their time inactive below the surface and feeding (Table 2). Although there was a decrease in meadow feeding during the winter, there was no significant difference ($P=0.210$) in the proportion of time spent feeding in meadow areas during summer, fall, and winter. Haypile feeding in the winter (11.4%) increased the total amount of time spent feeding to its highest level (28.2%). Haypile feeding was not observed during summer and fall.

Because pikas eat leaves and stems, a low energy food source (Golley 1961), and the bulk of food that can be digested at one meal is limited by stomach size, they need to feed frequently to maintain their high metabolic rate. Frequent feeding activity has been observed in other small mammals (rodents) which feed strictly on vegetation (Davis 1933, Hatfield 1940). The fairly consistent amount of time spent feeding during all seasons is probably related to low forage quality and continuous activity throughout the year.

Activity below the surface increased significantly ($P<0.001$) from summer (15.4%) to fall (28.2%) but decreased again from fall to winter (16.6%). There was no significant difference in inactivity below the surface in summer (33.9%)

and fall (30.5%); however, there was a significant increase ($P=0.001$) in inactivity below the surface during the winter (55.2%).

Pair-wise comparisons (Student's *t*-test) were made between summer and fall for haypiling, perching, investigation, and social behavior. Significantly ($P=0.001$) greater time was spent haypiling (7.1%) during the summer than during fall (1.4%). Decrease in haypiling activity during the fall has been seen in other pika populations (Smith 1974b, Barash 1973, Conner 1983). Conner (1983) reported the amount of time spent haying in August and September as approximately 60% and 40%, respectively, of aboveground activity during hours of peak activity (0700-1100 h). By October, haypiling had almost ceased (3.3%). Even when different methods of calculating the percentage of haypiling time are considered, Conner still showed a much larger proportion of haying time for August and September than I found in the current study.

Decreased haypiling activity during the fall may be related to decreasing forage quality. The protein and moisture content of available vegetation declines with drying in the fall (Sharif and West 1968, Johnston et al. 1968, Millar 1971, Graham 1978). Peak haypiling coincides with the peak nutritional value of the available vegetation (Millar 1971).

Pikas spent significantly ($P < 0.001$) more time perching during the summer (12.0%) than during fall (5.0%). Perching was often associated with sunning by the pikas and seemed less evident on rainy, overcast days. During the fall, rain and snow showers increased, and temperatures decreased as cold fronts passed.

Decreased time perching in my study differed from reports by Conner (1983) for pikas in Colorado. Conner reported a slight increase in the proportion of time spent perched from September to October. This was due to an increase in the average time spent perched, even though the frequency of perching in Colorado, as in this study, decreased steadily into winter.

There was no significant difference in time spent in investigation between summer (8.2%) and fall (9.3%). Pikas did display significantly ($P = 0.010$) greater time in social behavior during the summer (1.0%) than during the fall (0.3%). Social interactions (vocalizations, chasing) were used to secure and maintain territories centered around a haypile. Because of this, social intolerance and interactions should peak during the late summer when juveniles were dispersing and haypiling activity was most intense (Barash 1973, Markham and Whicker 1973, Lutton 1975).

The proportion of time involved in social behavior, although greatest during the summer, constituted a minute proportion of overall time (1.0%). No other studies have reported the amount of time actually spent in vocalization or chasing behavior, and this makes comparisons difficult between my data and data from other studies. However, by using estimates of the number of chases/hour from other studies (Barash 1973, Lutton 1975) and the average duration of a chasing bout (1.0 min., this study), an estimate of amount of time devoted to chasing during daylight hours can be obtained. Lutton (1975) reported an average of 1 chase/hour in July for pikas near the Rocky Mountain Biological Laboratory, Colorado. This corresponds to approximately 1.7% of a pika's time devoted to chasing during daylight hours. Barash (1973), in Glacier National Park, found rates of 1.8 to 2.6 chases/hour for late July and early August. In this instance, chasing during daylight would occupy 3-4% of the animal's time. Estimates (chasing only) based on Barash's and Lutton's data are two to four times higher than the time devoted to social behavior (vocalizations and chasing) in my study for the summer.

The comparatively lower rate of social interactions in this study may be related to the degree of habitat saturation. The rockslides in the study areas approached island habitat situations. Connections with more extensive

talus slopes were often patchy. Small island size, low colonization rates among distant islands, and high extinction rates associated with small populations often result in unsaturated habitats (Smith 1974a). The resulting low social pressure and competition on adults and juveniles alike could explain the less intense social interactions observed in this study.

The amount of vocalization and chasing was greatest during late summer but did not occur with great intensity. Vocalizations at night were quite rare and infrequent. During the winter a vocalization was heard on only one occasion. Yet pikas were active both on the surface at night during summer and fall and under the snow in winter. Smith (1974b) reported that the amount of aboveground activity in a pika population was correlated with frequency of calling. Conner (1983) also stated that short call rate was highly correlated with surface activity. He felt this relationship might be valuable as an indirect measure of surface activity at night or under snow cover. In my study vocalization rate was not related to surface activity and would not have been an accurate indicator of surface activity at night or under snow cover.

Seasonal Variation in Daily Patterns of Selected Activities

Differences in the mean percentage of time active per 30 minutes throughout the day for five selected activities during the summer, fall, and winter are shown in Figures 3, 4, and 5. The activity types selected were feeding, activity below surface, inactivity below surface, perching, and haypiling. These activities were selected because they involved a major portion of the animals' time. Due to lack of visibility, perching and haypiling activity were not distinguished for night hours. Data for nighttime feeding were approximations based on the duration of active time spent away from the haypile region in known feeding areas.

During the summer (Figure 3), there were no significant differences ($P=0.422$) in the mean percentage of time spent feeding during morning, midday, late afternoon, and night. Activity below the rock surface did vary ($P=0.038$) with a peak in the morning (20.7%) and a low during late afternoon (10.0%). Activity below the surface during midday and nighttime did not differ significantly from morning. There was a significant difference ($P=0.002$) in inactivity below the rock surface throughout the day. Inactivity below the surface was greater at night (51.5%) and midday (40.4%) than during morning (28.1%) and late afternoon (26.4%).

SUMMER 1984

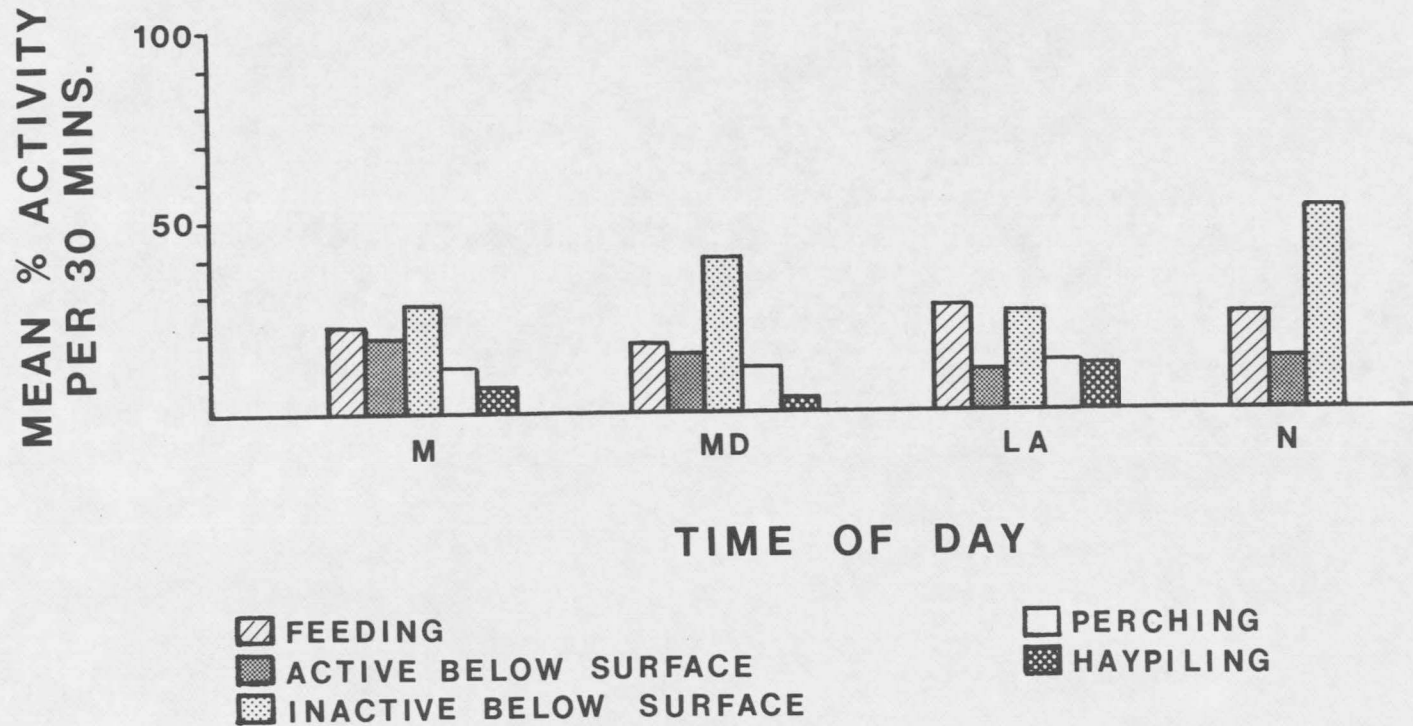


FIGURE 3. Mean percentages of time active per 30-minute interval throughout morning (M), midday (MD), late afternoon (LA), and night (N) for five activity types during the summer.

There was no significant difference ($P=0.913$) in time spent perching throughout the day. The proportion of time spent haypiling was significantly greater ($P=0.047$) in the late afternoon (11.8%) and morning (7.0%) than during midday (2.7%).

A comparison of the mean percentage time active per 30 minutes for the five selected activities at different times of day during the fall season is shown in Figure 4. There was a significant difference ($P<0.001$) in feeding times throughout the day due to reduced nocturnal feeding. The amount of feeding activity peaked during the morning (34.6%) and late afternoon (26.5%) and decreased at midday (19.2%).

There was no significant difference ($P=0.240$) in activity below the rock surface among morning, midday, late afternoon, and night. However, there was a significantly greater proportion ($P<0.001$) of time spent inactive below the surface at night (59.6%) than at any other time of day. There was no significant difference in below surface inactivity during morning (23.7%), midday (33.4%), and late afternoon (31.3%).

Perching and haypiling were compared for morning, midday, and late afternoon only. No significant differences ($P>0.05$) were found in either activity for the three daytime periods.

FALL 1984

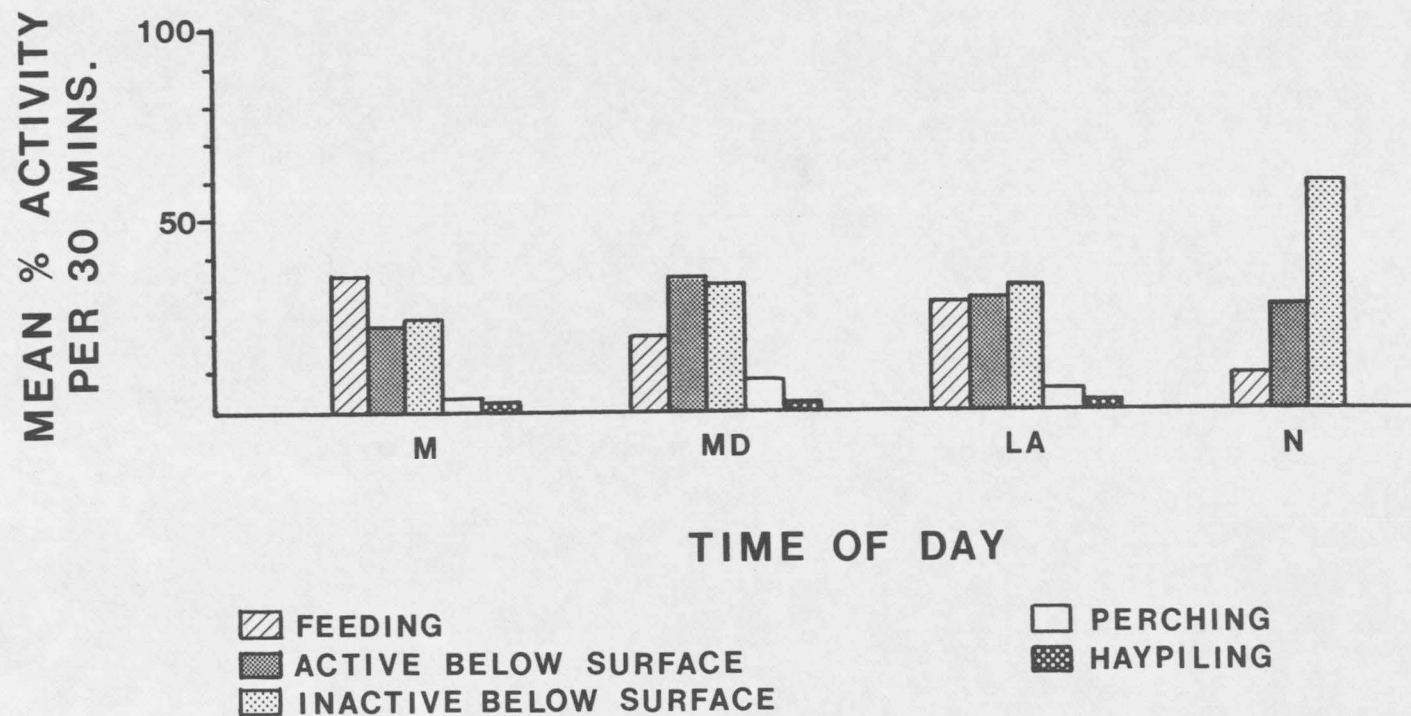


FIGURE 4. Mean percentages of time active per 30-minute interval throughout morning (M), midday (MD), late afternoon (LA), and night (N) for five activity types during the fall.

In the winter, there were no significant differences in the proportion of time the pikas spent feeding in meadows ($P=0.636$), feeding on the haypile ($P=0.907$), active below the surface ($P=0.561$), and inactive below the surface ($P=0.754$) at different times of day (Figure 5).

Nocturnal Activity in Relation to Moon Phase

No significant differences were found in the mean percent activity per 30 minutes among seasons for each phase of the moon ($P>0.20$) (Table 3). Thus, seasonal observations for each moon phase were combined and compared with an analysis of variance. The phase of the moon did not have any measurable effect ($P=0.862$) on the proportion of nighttime activity of the pikas (Figure 6) throughout summer, fall, and winter.

This is consistent with findings for some nocturnal species. Lord (1964) found no correlative periodicity of rabbit activity in relation to phase of the moon. Getz (1968) found greater activity on cloudy nights than on clear nights in the red-backed vole but also found no suppression of activity on nights of full moon (clear sky).

Moon phases do affect the activity of some small mammals. Fafarman and Whyte (1979) found that increasing moonlight during periods of low rainfall tended to depress nighttime roadside counts of cottontail rabbits in Texas. A

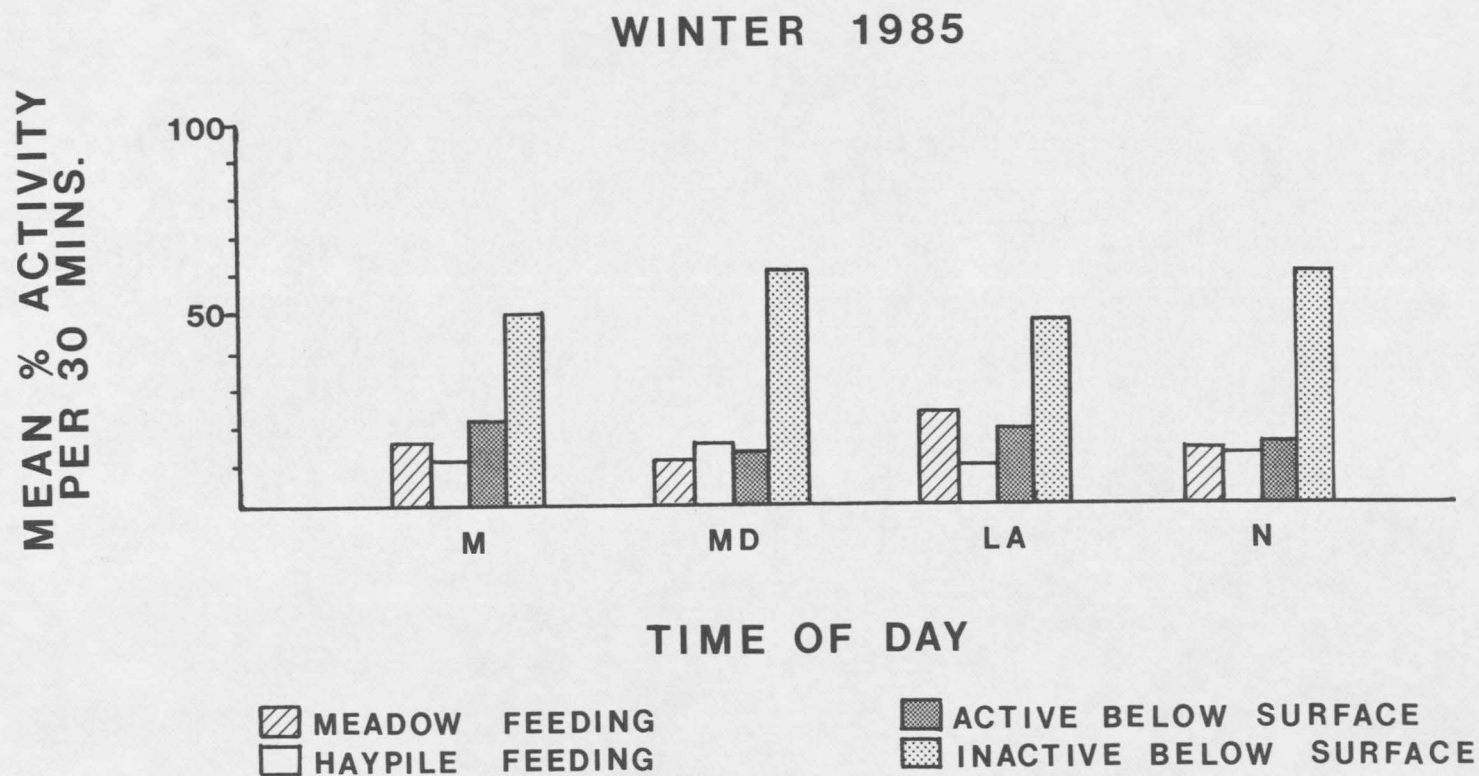


FIGURE 5. Mean percentages of time active per 30-minute interval throughout morning (M), midday (MD), late afternoon (LA), and night (N) for four activity types during the winter.

TABLE 3. Mean percentage nighttime activity per 30-minute interval for each moon phase during summer, fall, and winter. Night data included all 30-minute samples from sunset to sunrise.

Moon Phase	^b $\bar{X}$ Percent Activity (n)			^a ANOVA Results	
	Summer	Fall	Winter	F	P
First Quarter	<u>47.6</u> (17)	<u>45.3</u> (22)	<u>56.2</u> (14)	0.366	0.700
Full Moon	<u>44.8</u> (24)	<u>50.8</u> (12)	<u>34.5</u> (6)	0.461	0.639
Last Quarter	<u>50.8</u> (29)	<u>41.2</u> (23)	<u>34.6</u> (19)	1.269	0.287
New Moon	<u>44.3</u> (17)	<u>47.8</u> (33)	<u>37.1</u> (14)	0.366	0.701

^a From ANOVA testing for heterogeneity among seasons.

^b Means sharing a common underline are not significantly different ($P > 0.05$) by the Student-Newman-Keuls test.

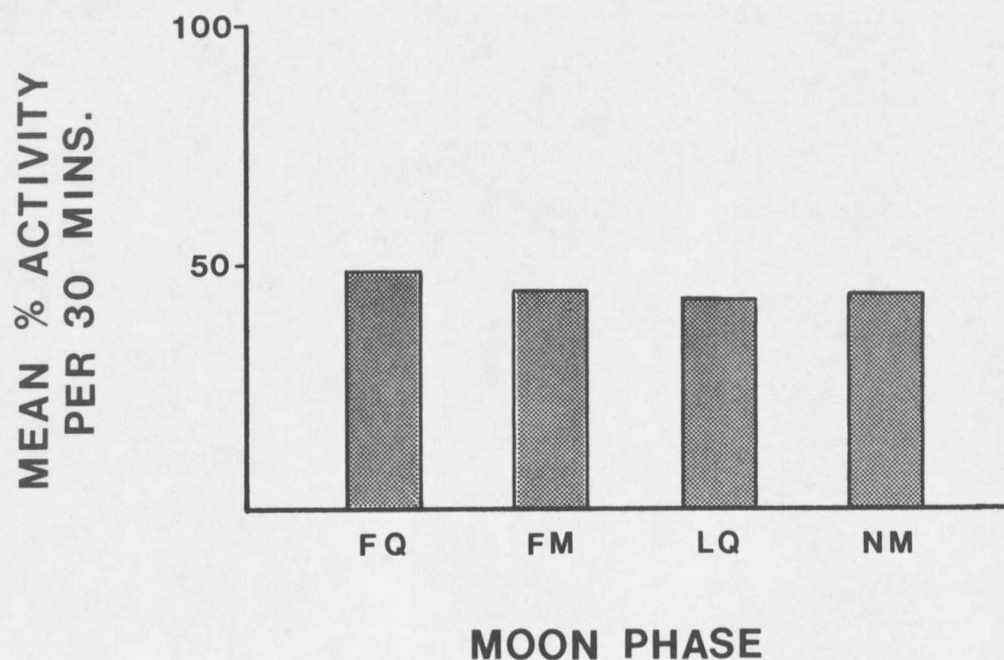


FIGURE 6. Combined seasonal observations of mean percentage nighttime activity per 30-minute interval for first quarter (FQ), full moon (FM), last quarter (LQ), and new moon (NM). Night data include all 30-minute samples from sunset to sunrise for summer, fall, and winter.

variety of nocturnal rodents (Clethrionomys gapperi, Napaeozapus insignis, Dipodomys ordii, Microtus pennsylvanicus, Onychomys leucogaster) show increased activity on cloudy and moonless nights and decreased activity with increasing moonlight and a full moon (Blair 1951, Doucet and Bider 1969, Jahoda 1973, Vickery and Bider 1981). Moon phase has a similar influence on shrews with more activity during the new moon and less during the full moon (Doucet and Bider 1974, Vickery and Bider 1978).

The decline in activity with increasing moonlight in small rodents has been suggested as an adaptation to avoid predators that use visual detection of prey. Some small desert rodents have been shown to adjust their use of microhabitats to take advantage of heavy cover and shadows during periods of bright moonlight (Lockard and Owings 1974, Kaufman and Kaufman 1982, Price et al. 1984). Pikas may also make use of microhabitats to minimize predation risk and reduce the influence of moonlight. Due to the nature of their habitat, pikas could easily use rock shadows or even restrict movement completely below the rock surface when traveling to adjacent feeding meadows. By feeding on vegetation near the rockslide margin, they would have easy access to a relatively secure retreat from many predators. Moonlight should have little influence on activity of pikas using microhabitats in this manner.

Effect of Weather on Nocturnal Feeding Activity

During the summer, weather conditions had little measurable effect on nocturnal foraging activity ($P=0.779$) (Table 4). In the fall, there was a significant difference ($P=0.018$) in the amount of nocturnal meadow feeding under the different weather conditions (Table 4). There was a decrease in meadow feeding activity during overcast periods with rain or snow (1.1%). By comparison, nocturnal meadow feeding activity on clear/cloudy nights averaged 13.8%.

TABLE 4. Nocturnal meadow feeding activity (mean percentage activity/30-minute interval) under varying weather conditions (night period - 2200-0400 h). There were no significant differences in activity between weather conditions during summer, but fall activity was significantly different (Student's t-test).

Weather Conditions (% Activity)						
	Clear/Cloudy (1°-4°C)		Overcast/ Raining		t	P
	X	(SE)	X	(SE)		
Summer n	26.3 (30)	(30.6)	24.0 (30)	(32.1)	0.282	0.779
	Clear/Cloudy (-4° to 3°C)		Rain/Snow		t	P
	X	(SE)	X	(SE)		
Fall n	13.8 (30)	(21.7)	1.1 (18)	(4.7)	2.444	0.018

Although no significant differences in the distribution of time spent meadow and haypile feeding were found during winter (Table 5), the two appeared to be inversely related. During clear nights with bitter cold temperatures near or below -17°C , pikas demonstrated a higher percentage of haypile feeding (23.3%) as compared to active meadow feeding (11.1%). This same relationship occurred on evenings during which it was snowing or had snowed earlier in the day. Because sample sizes were small and the differences were not significant, more extensive winter data is needed to confirm whether this is a valid trend.

TABLE 5. Nocturnal winter feeding activity (mean percentage activity/30-minute interval) under different weather conditions (night period - 2200-0400 h). There were no significant differences between meadow and haypile feeding under different weather conditions (ANOVA).

	Weather Conditions (% Activity)					
	Clear/Bitter Cold (-13° to -24°C)		Clear/Ptly Cldy (-12° to -7°C)		Snowing or Snow Earlier in Day	
	X	(SE)	X	(SE)	X	(SE)
Meadow Feeding	11.1	(27.2)	16.7	(28.7)	0	(0)
n	(6)		(15)		(3)	
Haypile Feeding	23.3	(27.3)	6.5	(14.3)	22.2	(38.5)
n	(6)		(15)		(3)	
P	0.456		0.227		0.374	

Nocturnal Activity Patterns

My observations demonstrated significant nocturnal activity that occurred not only in summer but throughout winter as well. The amount of nighttime activity was generally similar to midday activity, and there was no significant difference in the amount of nocturnal activity between summer, fall, and winter (Table 1). Fall was the only season which had significantly less ($P < 0.001$) nocturnal activity than activity during other daily periods.

Some authors have reported hearing pikas call at night, but little other evidence of night activity has been reported (Dalquest 1948, Krear 1965, Smith 1974b). Both Smith (1974b) and Krear (1965) reported pikas to be inactive at night at high altitudes. Smith (1974b) reported some nocturnal feeding, calling, and movements on nights of a full moon in pikas at low elevations in Bodie, California, during summer. Smith (1974b) was uncertain whether pikas engaged in an ecologically significant amount of activity at night.

Because visual observations were inadequate at night, determination of activity was based on radiotelemetry. Based on the knowledge of location as determined by the radio signal and the verified daytime activity in that location, inferences were made regarding the type of nighttime activity in which the pikas were engaged. The

majority of nocturnal activity during summer was spent feeding in adjacent meadows (Figure 3). This meadow feeding did not differ significantly ($P=0.422$) from diurnal feeding. In summer, weather conditions were usually good with mild nighttime temperatures which provided ideal feeding conditions. Severaid (1955) also suggested that pikas may forage extensively during mild summer nights.

During the fall pikas showed significantly less total nocturnal activity than during diurnal periods (Table 1). Nocturnal meadow feeding was significantly less ($P<0.001$) than diurnal meadow feeding in the fall (Figure 4) and nocturnal meadow feeding during the summer ($P=0.006$). Although less than winter nocturnal meadow feeding (13.2%), fall nocturnal feeding (9.1%) was not significantly different. During the fall, there was a significant decrease ($P=0.018$) in meadow feeding activity on overcast nights with rain or snow (Table 4). This decreased nocturnal activity could have resulted from a combination of inclement weather conditions and a decline in the nutrient quality of available vegetation (Johnston et al. 1968, Millar 1971, Graham 1978) reducing the energetic benefits of meadow feeding. Pikas possibly made slight use of haypiles during inclement weather, but if so, this was not detected. Barash (1973) stated that inclement weather seemed to inhibit pika aboveground activity. Haga (1960) also observed reduced

activity in the Japanese pika during rainy or cold, windy weather.

During the winter, nocturnal activity was recorded in meadow feeding areas but to a lesser extent than in summer. Activity, inferred to be haypile feeding, was increasingly common. By combining the time spent meadow (13.2%) and haypile (12.6%) feeding, it was apparent that pikas spent essentially the same amount of time feeding at night during the winter as they did meadow feeding at night during the summer (25.1%).

It seemed unlikely that a significant amount of haypiling or perching occurred at night. Haypiling trips were much shorter than foraging trips (this study, Barash 1973) and included frequent movement from a haypile to a foraging area and back. This type of movement could be distinguished by changes in radio signal locations and was not a common component of nocturnal activity. This supports the suggestion by Severaid (1955) that pikas may confine most of their haypiling to daylight hours. There were no nighttime observations of perching in areas frequented in the daytime. Perching during the day often involved resting and sunning. It seemed unlikely that a pika would rest for any length of time on the surface in the dark when visibility was poor and temperatures were often cold.

Body Temperature

From 29 September through 31 October 1984, a total of 157 measurements of body temperature were obtained by radiotelemetry from two adult pikas (one male, one female) in the field over an ambient temperature range from -11.1 to 21.1°C . The mean body temperature was 37.1°C and ranged from 33 to 40°C .

Although body temperature was not monitored for a continuous 24-hour period, the 6-hour and 3-hour observation periods in October provided 24 hours of body temperature measurements for both pikas. There was no correlation of pika body temperature with ambient temperature ($r^2=0.001$, $P=0.826$). Figure 7 illustrates the relationship of body temperature of pika No. 9, an adult female, with ambient temperatures ranging from -11.1 to 4.4°C . Mean subcutaneous body temperatures for both pikas during diurnal and nocturnal periods were similar (Table 6).

TABLE 6. Mean subcutaneous body temperatures ($^{\circ}\text{C}$) for two adult pikas during daytime and nighttime (1900-0700 h) periods over varying ambient temperature ranges during October 1984.

Pika No.	X T_B	X Day T_B	X Night T_B	T_A Range $^{\circ}\text{C}$
7	36.8	36.1	37.4	-1.1 to 21.1
9	37.8	37.5	38.2	-11.1 to 4.4

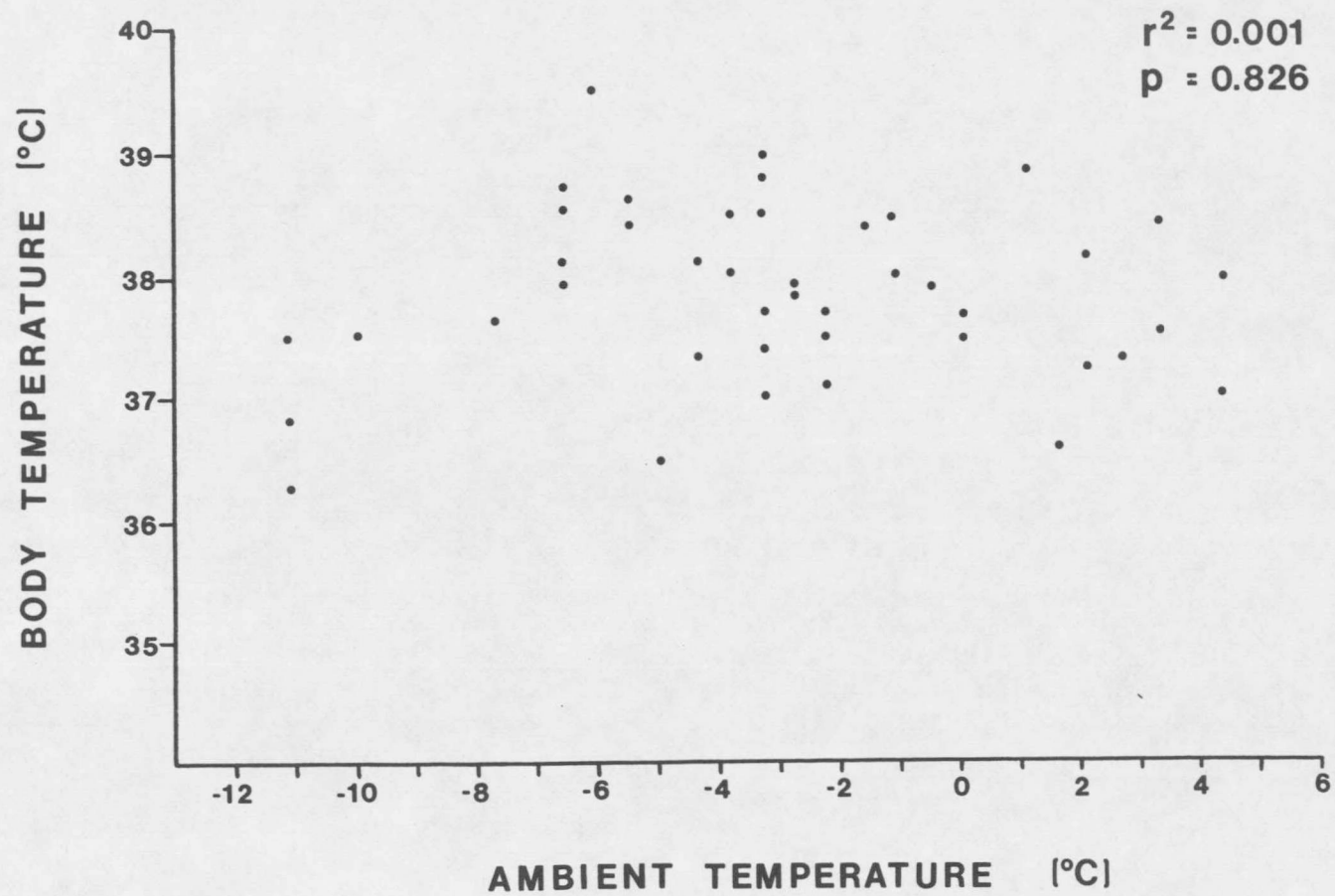


FIGURE 7. Subcutaneous body temperature for pika No. 9 over an ambient temperature range from -11.1° to 4.4°C for 16-31 October 1984.

Aspects of Winter Survival

Radiotelemetry data indicate that pikas do not hibernate but remain active year round, which is consistent with the findings of other authors (Severaid 1955, Haga 1960, Krear 1965, MacArthur and Wang 1973, Markham and Whicker 1973). They have high metabolic rates and good insulation (MacArthur and Wang 1973) which enables them to maintain a high body temperature regardless of ambient temperature. Since they feed on vegetation (leaves, stems, and litter), which has a low energy content relative to seeds and storage organs (Golley 1961), they must feed regularly to maintain their high metabolic rate. This need to feed frequently presents a problem for winter survival when energy (food) sources may be limited.

Part of the pika's winter survival strategy involves the construction of a haypile which seems to act as a supplemental food source. The amount of stored vegetation in a haypile is not considered to be sufficient to serve as the sole winter food source based on utilization rates by captive animals (Millar and Zwickel 1972a) and metabolic studies (Johnson and Maxell 1966). Supplemental, subnivian foraging on dried vegetation and lichens is assumed (Hayward 1952, Millar and Zwickel 1972a, Conner 1983) since rates of mortality do not differ among animals in different habitat

types with varying amounts of stored haypile vegetation (Millar and Zwickel 1972b).

During the winter, in my study activity was completely subnivian. Pikas have been known to tunnel in the snow (Severaid 1955, Krear 1965, Kawamichi 1968, Markham and Whicker 1973, Conner 1983); however, in this study no tunnels to the surface were observed. During the winter of 1984-85, natural openings existed in the snow until late February. At these times temperatures a meter within the rockslide near the haypile were approximately the same as ambient air temperatures which were measured as low as -17°C . Pikas could be exposed to severe temperatures when using haypiles and moving through the rocks near the surface. When snow cover on the rockslide was complete it acted as an insulating blanket, and temperatures a meter within the rocks were maintained from -3 to -2°C regardless of ambient temperature. Exposure of pikas to cold temperatures has also been reported by Conner (1983) and Paddock (1961), who observed pikas on windswept surfaces in the winter on Niwot Ridge, Colorado (3,200 m).

Activity patterns changed to some degree during the winter, and these changes should enhance winter survival. In winter, the primary priority for energy use should be thermoregulation. Since feeding is crucial in providing the energy needed for thermoregulation, it should be the

activity of the highest priority (Wunder 1984). By decreasing the total amount of activity in the winter and limiting activity primarily to feeding, energy could be conserved and the necessary caloric requirements met. Pikas maintained regular activity day and night throughout the winter, and the total amount of activity (42.9%) was not significantly different than summer (50.5%). However, significantly ($P=0.001$) more diurnal time was spent inactive below the surface (55.2%) than during summer or fall (Table 2). Activity below the snow surface was confined primarily to foraging in meadow areas and haypile feeding. Combined meadow feeding and haypile feeding estimates showed that feeding time was increased slightly, although not significantly, during the winter.

The overall intensity of winter activity was more reduced than in summer and fall. Activity in the winter was often characterized by a lower rate of fluctuation in radio signal volume. During active summer periods, frequent extreme variations in the radio signal volume were common. Visual observations confirmed that these periods of fluctuation signified rapid changes in location. Slight variations in volume were associated with simple changes in body position or head movements while the pika perched on or below a rock. Winter activity observed in this study suggested that the pikas maintained frequent periods of

feeding and similar rates of feeding as in summer and fall by utilizing haypiles, especially during unfavorable weather. They decreased energy expenditure by decreasing intensity of activity.

Conner (1983) and Millar and Zwickel (1972a) have suggested that the haypile is used as an auxiliary food source for insurance during extremely inclement weather and unpredictable seasonal changes that would reduce the benefit of active meadow feeding. No significant differences were found in winter between nocturnal meadow feeding activity and haypile feeding under different weather conditions. During periods of extreme cold weather (-13 to -24°C), there seemed to be more low level activity near the haypile (haypile feeding) than meadow foraging. If this trend could be validated with more extensive data, it would provide more direct evidence to support the suggestions of Conner (1983) and Millar and Zwickel (1972a).

The pikas in this study did not spend a large proportion of time haypiling when compared with animals in more alpine situations (Conner 1983) but still accumulated fairly large haypiles. The quantity of vegetation stored has been shown to vary depending on the habitat, the amount of vegetation available, and the age and sex of the individual (Millar and Zwickel 1972a). Other studies indicate that mortality rates do not vary significantly

between animals with different sized haypiles (Millar and Zwickel 1972b), and reproductive success in the spring does not show any correlation with the size of haypiles (Millar 1971).

Because the haypile probably serves as a "security" food source, the amount of effort put into acquiring this "security" may be related to the severity and length of winter. Pikas in alpine and subalpine areas generally experience longer periods of snow cover, severe temperatures, and later initiation of vegetative growth in the spring than pikas at lower altitudes. The timing of snowmelt in high elevations can be unpredictable and may stress the overwintering pikas and influence reproduction (Smith 1978). Having some stored vegetation available may be more critical for pikas inhabiting regions with long, severe winters and unpredictable spring snowmelts.

More time devoted to haypiling does not necessarily imply larger haypiles for these animals. In alpine sites, vegetation may be dwarfed and sparse relative to more lush meadows at lower altitudes. In a habitat with a sparsely vegetated foraging meadow, more time may be required to accumulate a haypile equivalent to or even smaller in size than a haypile constructed in a lush meadow habitat. Alpine plants often have a higher energy content than those at lower elevations (Golley 1961, Bliss 1962, Johnston et al.

1968), and this may partially compensate for smaller haypile sizes in alpine sites. However, Johnson and Maxell (1966) found no relationship between caloric value of haypiles and altitude for pikas at elevations from 2,590 to 3,930 m in southwestern Colorado.

Pikas may also use abandoned haypiles in adjacent territories during the winter. A radio-collared pika in this study was apparently using the haypile of a deceased radio-collared neighbor. Pikas have been observed stealing vegetation from neighboring haypiles during summer and fall while the owners were away (this study, Lutton 1975, Kawamichi 1976). An animal could easily increase forage availability by using an abandoned haypile during the winter.

CONCLUSIONS

This study provided quantitative information on diurnal and nocturnal activity patterns during summer, fall, and winter for a pika population in Gallatin Canyon, southwestern Montana. The extent of meadow feeding and haypile feeding during the winter was estimated, and seasonal changes in behavioral patterns were related to winter survival strategies. The relationship of pika body temperature to ambient temperature was investigated, as well as the influence of weather on activity patterns.

Total pika activity was significantly greater in the fall than during winter. However, there was no significant difference between summer-fall and summer-winter activity.

Throughout summer and fall, pikas showed small peaks in activity during the morning and late afternoon as reported by other authors (Hayward 1952, Broadbooks 1965, Barash 1973, Smith 1974b). In this study, these activity peaks continued throughout the winter. Despite these morning and late afternoon activity peaks, there was no significant difference in mean proportion of activity among the four daily periods.

There was no significant correlation between the mean proportion of pika activity and ambient temperature

throughout summer, fall, and winter. There appeared to be no correlation between pika body temperature and ambient temperature.

Throughout the seasons, pikas spent a major portion of their time inactive below the talus surface and feeding above the surface. The proportion of time spent meadow feeding, although less in the winter, did not differ significantly throughout the seasons. Inactivity below the surface increased significantly during the winter. There was significantly more time spent in haypiling, perching, and social behavior during the summer than in the fall.

During the summer, there was no significant difference in feeding time throughout the day and night. Inactivity below the surface was significantly greater at night and midday. Haypiling time was greatest during morning and late afternoon. During the fall, feeding time peaked during morning and late afternoon and was significantly less at night. Inactivity below the surface was significantly greater at night. In the winter, there were no significant differences in the proportion of time pikas spent meadow feeding, haypile feeding, active below the surface, and inactive below the surface throughout the day.

Moon phase did not have any measurable effect on the amount of nocturnal pika activity throughout summer, fall, and winter. During the summer, weather conditions had

little measurable effect on nocturnal foraging activity. In the fall, there was a significant decrease in nocturnal meadow feeding activity during periods with rain or snow. During the winter, although no significant differences were found, a decrease in meadow feeding seemed to correspond with increased haypile utilization on nights with temperatures near or below -17°C or snow. If this trend could be validated with more extensive winter data, it would contribute support to the suggestion of the haypile as an auxillary food source during inclement weather that would reduce the benefit of active foraging.

Nighttime activity did not vary significantly between summer, fall, and winter. The majority of nocturnal activity during the summer was spent feeding in adjacent meadows. In fall, pikas showed less nocturnal activity than during diurnal periods and significantly less nocturnal feeding than in summer. A combination of inclement weather conditions and a decline in the quality of available vegetation could have contributed to the decrease in activity. Nocturnal meadow feeding during the winter occurred to a lesser extent than during summer, but it was not significantly different. This was offset by haypile feeding.

Activity patterns changed some during the winter. Pikas maintained regular activity periods, and the total

amount of activity was not significantly different from summer. The greatest amount of time was spent inactive below the surface and included a significant increase over summer and fall in diurnal inactivity. Activity below the surface was confined primarily to foraging in meadow areas and low level activity near the haypile (haypile feeding). Combined meadow feeding and haypile feeding estimates showed feeding time to be comparable with summer and fall.

The overall intensity of activity was more reduced and consisted of increased low level activity that did not involve major changes in location. This increase in low intensity activity during the winter could act as a mechanism to conserve energy or could reflect restriction of activity due to snow.

In this study, pikas spent less time haypiling than animals in more alpine situations (Conner 1983). The amount of time devoted to haypiling may be related to the severity of the environment, longevity of the winter season, and availability of vegetation. Pikas in alpine and subalpine areas may experience longer periods of snow cover, severe temperatures, and later initiation of vegetative growth. A haypile may be more crucial in these alpine areas and, if the vegetation is sparse, may require more time to collect sufficient stores to serve as insurance during an unpredictable winter.

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