

Evidence for Fine Scale Adjustment in Circadian Rhythms in  
Yellow-Bellied Marmots According to Burrow Location,  
Photoperiod, and Local Ambient Temperature

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## Introduction

Biological timing has been observed in almost all species with the exception of those that evolved in habitats such as lightless caves or abyssal oceans (DeCoursey et al. 2000). These 24-hour cycles, termed circadian rhythms, have been shown to be not merely the simple reaction of the organism to changing environmental stimuli, but to also be the product of endogenous rhythms of a physiological nature (Aschoff 1965). The hypothalamic suprachiasmatic nucleus (SCN) has been identified as one of the structures in the brain that generates and regulates circadian rhythms, aiding the organism in adjustments that regular daily behavior requires. Alteration or destruction of even part of the SCN results in disruption of many of the normal behavioral, physiological, and even endocrine rhythms in some species of rodent (Rusak 1982). These circadian rhythms can be astonishingly precise in their repetitive timing of activities over multiple 24-hour cycles (Takahashi and Zatz 1982). For example, cycle length variation in nocturnal rodents has been shown to be less than 3 minutes (Takahashi and Zatz 1982). Circadian rhythms are controlled endogenously by genetics, several genes of which have already been uncovered (Page 1994).

However, these circadian rhythms are not free-standing internal physiological mechanisms independent of external input. The pacemaker of these circadian rhythms, the SCN, receives input from the external world and corrects to external, typically abiotic cues, such as temperature and the light-dark cycle (DeCoursey et al. 2000). This mechanism is called entrainment, and is thought to have evolved in order to allow more flexibility in behaviors than when the organism is simply driven by the cyclic environmental cues of light and dark or ambient temperature (Roenneberg and Merrow 2001). These rhythms have been shown to be most affected by photoperiod (Takahashi and Zatz 1982). Thus, though there is a genetic component involved, an external stimulus is also required to maintain the regular periodicity of the circadian rhythm. Under laboratory conditions, these rhythms are typically synchronized to the artificial environment of the lab, but under field conditions, behaviors mediated by circadian rhythms are synchronized with and by the environmental abiotic periods they experience in an interdependent system (Enright 1970). Behaviors then, are a result, not only of the endogenous rhythms maintained internally by the organism, but also by the external cues that it experiences as a part of its daily activity. Thus, these circadian rhythms have been shown to be a flexible mechanism, rather than a rigid timing system.

Since circadian rhythms play an important role in the timing of many diverse daily physiological and behavioral functions of almost all living things, including plants and even individual cells (Roenneberg and Merrow 2001), they are believed to be highly adaptive and essential for the survival and optimal fitness of organisms (DeCoursey et al. 1997). When SCN-lesioned wild-caught antelope ground squirrels were released into an enclosure for observation, it was found that they behaved normally in all respects except that they became arrhythmic, and were active more often at night than ground squirrels with intact SCN. This was despite the fact that this species is typically strongly diurnal (DeCoursey et al. 1997). In addition, in a study of mortality of SCN-lesioned squirrels, 66.7% of SCN-lesioned squirrels were killed by predation while only 30.0% of intact squirrels succumbed (DeCoursey et al. 2000).

The correct functioning of a circadian rhythm can be presumed to be essential to survival, as the timing of activities throughout the day for an organism could spell the difference between life and death. Circadian rhythms affect all behaviors, especially noticeable ones such as feeding and sleeping. An organism who feeds at an in-optimal time will suffer a fitness cost,

whether the cost is due to increased predation or because of a physiological cost, such as feeding during periods of the day that are outside of one's thermoneutral zone.

Being active while aboveground ambient temperatures are not within an organism's thermoneutral zone exacts a thermoregulatory cost from the organism, while burrows rarely experience large fluctuations in temperature, regardless of time of day. One study found that burrows of the yellow-bellied marmot rarely deviate from 10°C (Svendsen 1976), despite the fact that daily temperatures in the vicinity of the study burrows regularly reaches 80°C or above (personal observation). It was found that Degu *Octodon degus*, a diurnal rodent found in semiarid environments, decreased the frequency of visits to patches of food when the patches were under intense heat, and therefore had a higher thermoregulatory costs for the animal (Bozinovic and Vasquez 1999). Thus, it would be optimal for organisms to engage in foraging before or after ambient temperatures rise above their upper critical temperature, often resulting in the most common pattern of circadian rhythms, where there are two activity peaks per day (Aschoff 1965).

Given this information, it can be presumed that circadian rhythms will be entrained to the habitat and external cues that an organism is exposed to, potentially even to subtle differences between environmental cues received by organisms living within a few kilometers of each other. Shelter location and orientation, especially burrows for ground-dwelling sciurids that rely heavily on these shelters, can affect the variation in environmental stimuli received by the resident organism. This affects their circadian rhythms, and thus, when they engage in fitness increasing behaviors such as foraging. The timing and amount of time spent foraging, which is reduced in a bimodal circadian pattern, is especially critical for organisms that hibernate and already have a reduced amount of time to acquire the resources they need to survive hibernation (Armitage et al. 1996).

The purpose of this study was to examine the behavioral time budgets and activity schedules of yellow-bellied marmots in the East River Valley and to compare those that resided on the floor of the valley near the eastern slope with those that resided up on the western slope of the valley in order to discover if the difference in sunlight and temperature schedules affected the activity schedules of the marmots residing in those burrows. The presence of circadian rhythms in yellow-bellied marmots has been demonstrated previously (Woods et al. 2002). Since marmot burrows are located on all parts of the valley slopes and floor, each burrow experiences its own microclimate of temperatures as it receives sunlight at different times of the day from its counterpart on the opposite slope or floor of the valley.

## **Materials and Methods**

### *Study System*

Yellow-bellied marmots (*Marmota flaviventris*) are semi-fossorial sciurids that inhabit much of the western United States, and are found in mainly cold areas and high elevations (Frase and Hoffmann 1980). This species hibernates during the winter, which limits the amount of time it has to reproduce and forage to approximately 4-5 months of the year (Armitage et al. 1996). Foraging time is crucial to these marmots because it is imperative that they attain a certain critical threshold weight in order to survive hibernation throughout the winter (Frase and Hoffman 1980). *Marmota flaviventris* is an organism whose foraging time is limited by the thermoregulatory costs of being abroad during the intense heat of the mountain sunlight. The thermoneutral zone (TNZ) for adults is in the range of 10 to 20 °C for adults and between 20

and 25 °C for juveniles (Armitage et al. 1991). The very adaptations that allow these marmots to survive the harsh winters of their habitat are the very physiological mechanisms that constrain their activity aboveground during the summer heat (Armitage et al. 1996). These herbivorous sub-alpine mammals typically live in colonies of several burrows in grassy meadows with rock outcrops and boulders or open, herb-covered talus slope (Svendsen 1976). Most burrows are located on hillside or the sides of cliffs such that the entrance to the burrow is at an angle, typically facing in a northeasterly or southwesterly direction (Svendsen 1976).

### *Data Collection*

Observations were conducted in the vicinity of Gothic, Colorado at an elevation of ~2900 m. The sites used in this study were North Picnic and Cliff, which are both situated on the west side of the East River Valley, and at Marmot Meadow, which is located on the east side of the East River Valley. The East River Valley is a valley that runs north-south, and consequently, sunset and sunrise for the west side of a north-south facing valley occurs almost an hour before sunrise/sunset for the eastern slopes of the East River Valley. The location of Marmot Meadow is located approximately a mile up the valley from the Gothic town site, on the eastern side of the valley floor, in a meadow surrounded by willows very close to the base of Avery Peak. The five burrows under observations were located on the southern-most section of the colony. One burrow was located at the edge of a grove of aspens that descended into the meadow, partially inside the aspen grove. The other four burrows were located within a 20 m radius of this burrow, but all in the open spaces of the meadow. Each location was dominated by a large boulder or a scattering of small boulders, with the exception of one, which had no apparent aboveground rock structural support. Burrows were dug under these rocks, often with multiple entrances within an area of 1 to 2 m<sup>2</sup> circumference. The burrow at Cliff is located underneath the prominent ridge halfway up the slope. It is situated between two ridges of rock, and is surrounded by willows, making the foraging ground very difficult to see. North Picnic is located approximately 3 miles up valley from Gothic, on the western slope of the valley. The burrows are located in a grassy and brush-covered, but tree-less section of the steep slope, approximately midway between the floor of the valley and the ridge line above. Burrows are located in several feet high brush at rock outcroppings.

In order to determine approximately when the marmots at each site began to be active, morning observations were begun before sunrise between 6:30 A. M. and 7:00 A. M. and continued until after 11:00 A. M., when the heat of the day caused a significant decrease in marmot activity. Afternoon observations were begun between 3:30 P. M. and 4:00 P. M. and continued until well after sunset. Sunset at Marmot Meadow occurred typically around 7:00 P. M., while shade fell on Cliff and North Picnic at approximately 6:20 P. M. and 6:05 P. M. respectively. Cloudy afternoons and mornings were also recorded in order to compare with days where sunlight was steady throughout the entire day.

Total active population and behavioral data were both obtained by the method of conducting a census of the colony under observation every two minutes from the time that observations began until the time that they ceased. Typically, for each observation session, between 120 and 150 censuses were conducted. Each census required less than a minute to complete, and was conducted with binoculars or a spotting scope, starting at one particular burrow and following the same sequence of burrows for each census. All visible marmots were noted and their behaviors tallied. Behaviors were divided into six classifications: sitting/lying,

running/walking, foraging, playing, vigilant, and grooming. Only marmots visible at the time of the census were recorded, regardless of whether it was evident where marmots that were hidden at the time of the census had gone. Although some marmots at each site were marked for recognition in other studies, individual markings of marmots were not recorded because of time constraints and because many of the marmots were unmarked at the beginning of the study. Despite this, repeated recordings of the same marmot during each census was controlled for by the rapid nature of the census and the distance between each burrow. Moving animals were followed to be sure of their direction and placement to control for this. Finally, for each census the presence of sunlight or shade on the burrows was noted and recorded at the end of each census.

Temperature information was also recorded using 1-Wire Thermocrons, which were tied to flags using strips of material and placed within 10 feet of the burrows that were under observation. Each Thermocron was positioned at approximately 8 inches off the ground in order to obtain an accurate reading of the ambient temperature to which marmots are exposed. The exception to this was Cliff, which was too inaccessible to readily place and recall the temperature devices before and after each observation session. Temperatures at Cliff were recorded by assuming that temperature ascension or decension followed a regular pattern that correlated with the presence or absence of sunlight. Thus, the Thermocron was placed near the researcher, and then the presence or absence of sun on both the burrow and on the Thermocron noted as the sun rose above or sunk below the horizon. The difference in times of sunrise/sunset between the placement of the burrows on Cliff and of the Thermocron were then calculated and applied to the Thermocron temperature readings to compensate for the difference in placement. The Thermocrons were placed before observation began, and then removed after the observation session was ended.

Data were analyzed using JMP 5.1 (SAS Institute). The following comparisons were made using 1-way ANOVA between marmot burrows on east- and west-facing sides of the valley: time of first direct sunlight exposure; time air temperature reached minimum TNZ; time air temperature exceeded maximum TNZ; time of peak number of marmots visible above-ground; time of maximum activity levels of marmots above-ground. Since yellow-bellied marmot activity is dependent upon the variation of ambient temperature because of the constraints of their thermoneutral zone, temperature was also examined as a function of time and presence of sunlight. Marmot thermoneutral zones range from approximately 10 °C to 25 °C dependent upon the age of the individual (Armitage 1991). Thus, the time that the ambient temperature rose above 10 °C and the time it rose above 25 °C were analyzed to determine the range of times the ambient temperature was inside the marmot thermoneutral zone.

Peak marmot activity was determined by examining the data for points in which the most marmots were visible when calling behavior was not exhibited. Several of the highest data points of marmots were included in the analysis in order to provide a better estimate of actual peak activity. Activity peaks where calling behavior were exhibited were excluded from this analysis, because these intervals were presumed to happen randomly, whenever a threat was spotted, without regard to regular activity patterns or external abiotic stimuli. Peak numbers of foraging and running marmots, which were determined to be the most active of behaviors, were also determined in the same way as those of peak total number of marmots active.

Observational data from afternoon observations was also analyzed, but is more limited because of the smaller number of afternoons available for observation. Marmot activity peaks were also analyzed from afternoon observation sessions, along with period of time the ambient

temperature of each burrow was inside the marmot thermoneutral zone in the same fashion as the analysis of the morning data. Behavioral ethograms were also constructed for a comparison of proportions of time spent engaged in each behavior according to east or west orientation of each burrow by averaging the number of observations of each activity and dividing by the total number of observations.

## Results

11 mornings of observations provide the data for this study, 7 at North Picnic and Cliff and 4 at Marmot Meadow. Sunlight struck North Picnic and Cliff at approximately 7:15 in the morning, while Marmot Meadow did not receive direct sunlight until 8:31 A. M., a difference of over an hour (ANOVA,  $F = 350.22$ ,  $P < 0.0001$ ). Temperature data indicated that ambient temperature at the location of the western burrows entered this range at approximately 7:20 A. M. and eastern burrows at approximately 8:24 A. M. A comparison of the time that the ambient temperature of the microhabitat surrounding each burrow entered this range, or reached 10 °C, was also made, and found to be different enough to be statistically significant (ANOVA,  $F = 6.557$ ,  $P < 0.0429$ ). It was also found that western burrows reached 25 °C at around 8:52 A. M. and that the eastern burrows examined reached this temperature near 10:34 in the morning. An analysis of the time of exit from the marmot thermoneutral temperature zone by orientation of the burrow found that the differences were statistically significant (ANOVA,  $F = 9.8334$ ,  $P < 0.0202$ ).

For western burrows at North Picnic and Cliff, peak times for total number of marmots active were observed to be around 8:26 A. M., while for eastern burrows at Marmot Meadow it was found to be 9:01 A. M. An analysis of this difference revealed that there was in fact a shift in activity peak between burrows on the western side and eastern sides of the valley (ANOVA,  $F = 4.475$ ,  $P < 0.0434$ ) (**Figure 1**). Time of highest number of marmots foraging and running was also examined in comparison with orientation of the burrow according to east and west, with 8:10 A. M. being the peak time for western burrows and 9:08 A. M. as the peak time for eastern burrows. Statistically, the variation between these peaks of foraging and running activity was found to be significant (ANOVA,  $F = 6.8625$ ,  $P < 0.0109$ ) (**Figure 2**).

Time of sunset for each location, or the time in which direct sunlight left the burrow was recorded, was recorded as averaging around 6:07 P. M. for burrows on the western slope and 7:18 P. M. for those on the eastern side, a statistically significant difference (ANOVA,  $F = 155.42$ ,  $P < 0.0002$ ).

Results indicate that the total number of marmots visible peaks for western burrows at 5:57 P. M. and 7:08 P. M. for eastern ones, which was found to be statistically significant (ANOVA,  $F = 8.3243$ ,  $P < 0.0059$ ) (**Figure 3**). However, in contrast to peak total marmot activity for both morning and afternoon, and peak number of marmots foraging and running in the morning, the peak number of marmots that were foraging and running during the afternoon observation sessions were not found to be statistically significant according to orientation (ANOVA,  $F = 3.7577$ ,  $P < 0.058$ ) (**Figure 4**). The peak time of marmot foraging and running on the west was found to be 5:33 P. M. and 6:04 P. M. for burrows on the eastern side of the valley.

Behavioral ethograms indicated that marmots living on the west side of the valley spend approximately 70% of their time sitting, 13% engaged in foraging, and 17% of their time running, playing, grooming themselves, and sitting in the vigilant attitude. However, marmots

that reside on the eastern side of the valley spend 51% of their time sitting, 30% of their time foraging, and 19% of their time engaged in other activities. All differences between proportions of behaviors were found to not be statistically significant with the exception of the difference in time spent foraging between burrows on the western side of the valley versus those on the eastern side of the valley (ANOVA,  $F = 7.1092$ ,  $P < 0.0258$ ) (**Figure 5 and 6**).

## Discussion

The goal of this study was to examine activity cycles of marmots in the East River Valley to determine if their activity was correlated with sun exposure, which differed because of burrow placement. It was first determined that sunrise, meaning the time of direct sunlight coming onto the burrow, did indeed occur over an hour later for burrows on the eastern side of the valley in comparison to those on the western side. A significant difference of over an hour was also shown for the time in the morning that the ambient temperature around the burrows rose above the lower critical temperature and also above the upper critical temperature of the marmot thermoneutral zone in the morning between western and eastern burrows. A one-way ANOVA then revealed that there was indeed a shift in activity time between burrows located on the western or eastern sides of the valley.

For the morning sessions, both the total number of marmots outside of the burrow at any given time and the total number of marmots engaged in the activities of running and foraging was found to have a significant difference in the time that the peaks occurred when analyzed by orientation of the burrow. Thus, the observational data from this study seems to indicate that both the environmental cues that might influence the circadian rhythms of the marmots and the marmot activity schedules are delayed over an hour for those marmots residing on the eastern side of the valley in comparison to those on the western slope.

Afternoon data were also analyzed, and the difference in the time that direct sunlight left the burrow, or sunset, occurred, and the difference between the times that the ambient temperature re-entered the marmot thermoneutral zone as the evening cooled were found to be statistically different when comparing burrows on the west and eastern sides of the valley. The peak time that the number of total marmots visible occurred was significantly different between eastern and western burrows, but the peak number running and foraging was found to not be statistically different between the two localities. Marmot behavior between the three locations did not differ significantly except in one respect, where it was found that proportion of time foraging differed significantly between burrows on different sides of the valley. The marmot behavioral proportions were also very similar to a study where the amount of time spent sitting and foraging was found to be between 40% and 60% and 12% to 22% respectively for different cohorts of marmot ages and sexes (Armitage et al. 1996).

One caveat of this study is that sample sizes are small, with only 11 mornings and 6 afternoons to examine when considering the data. This could account for the reason that the difference between peak foraging and running times was found to be not statistically significant for the afternoon sessions. However, it is interesting to note, that despite the small sample size, the difference between activity peaks of eastern and western marmots was still found to be significant. This provides very strong evidence for the presence of a shift in activity dependent upon locality because of the difference in timing of environmental cues.

Another issue that could have confounded the data was the inability of the researcher to see all of the marmots that were active outside of the burrow for every census. Tall grass, rocks,

and bushes often obscured part of the observation area, possibly hiding marmots from view. Proof for this is found in the calling episodes, where suddenly previously unobserved marmots appeared from out of tall grass and from shallow dents in the meadow. This was especially true for Cliff, where foraging behavior was almost unobserved because of the inability to see any of the marmot's home range, especially the foraging ground, except for the cliff where the burrow itself was located.

Other problems with this study include observer bias. While this was attempted to be controlled by refraining from observation when not engaged in a census, it is possible that the observer was influenced by previous knowledge of where marmots were located, and thus purposefully sought them out, rather than scanning at a continuous rate.

Despite the limitations of this study, it clearly demonstrates the potential for marmots living on the eastern side of the valley to have a circadian rhythm where activities are shifted over an hour difference from that of those living on the western slopes of the East River Valley. Though these marmots live within a few kilometers of each other, having a precisely entrained circadian rhythm has clear implications for fitness. Circadian rhythms require time in order to be entrained to a new set of abiotic environmental cues (). Thus, a marmot transplanted from the eastern side of the valley to the western side would still follow the pattern where its peak in activity would be around 9:00 A. M., which would be close to when the western burrows are experiencing an ambient temperature that would have a thermoregulatory cost for the marmot. There is an obvious fitness advantage to the marmots of each locality having circadian rhythms that are exactly entrained to the environmental cues of their microhabitat. Marmots with circadian rhythms that were asynchronous to the environmental cues of their microhabitat would not only suffer thermoregulatory costs, but might experience increased predation, and a loss in fitness.

The proportion of time spent in each activity is relatively the same for each side of the valley. However, more interesting conclusions might be drawn if the amount of time spent in each activity was examined according to orientation of the burrow. Possibly, one side of the burrow has more time in which to be active than the other, which would have large overall effects on the amount of time one set of marmots has to engage in feeding and other fitness increasing behaviors. An increase in the amount of time that can be allocated to foraging could well increase the chance of survival throughout the winter by allowing marmots on one side of the valley to more easily attain the threshold weight required to survive hibernation. Thus, not only quality of the microhabitat but also simple placement of the burrow might have drastic fitness effects on the marmots that live within.

Future studies on this subject will require more days of observation, especially in the afternoon, and also observation on overcast days, in order to determine if activity schedules are altered by the decreased midday temperature on cloudy days. Observation on overcast days might also help to determine which environmental cues are most important to marmot circadian rhythms. Another interesting question to explore would be to investigate whether marmots at North Pole Basin, at an elevation of 3400 m, which has a shorter growing season than the area around Gothic, exhibit the same activity cycle. The growing season in North Pole Basin is only 3 months long (Andersen et al. 1976), over a month shorter than the growing season at the elevation of Gothic. This means that marmots in North Pole Basin have an even shorter time than marmots lower down to acquire the resources they need to survive hibernation. This leads to the prediction that marmots in North Pole Basin would be more willing to incur thermoregulatory costs and predation risks in order to extend their foraging time outside the

times when the ambient temperature is inside their thermoneutral zone. This could compensate for the shorter growing season they experience. An alternative solution might be to dig their burrows in different habitats, such as in groves of trees, where the temperature is cooler than in the direct sunlight. This could also allow the marmots of North Pole Basin to forage longer to make up for the shortened growing season. A comparison between the activity schedules and behavioral ethograms of marmots around Gothic and in North Pole Basin could demonstrate how habitat and elevation have enormous effects on the behaviors of organisms merely by virtue of their location.

As many studies concerning circadian rhythms are devoted to discovering the genetic basis behind the timing of biological events, there is a dearth of information regarding circadian rhythms in natural settings. The application of the information presented above needs to be extended to other species and systems. Such a shift in activity may be non-existent in organisms that live in valleys that are oriented east-west or on flat plains or tundras. Activity shifts could also be important in attempts to re-locate organisms, as they will initially be operating on a circadian rhythm that is asynchronous to their new environment, which could be very detrimental in terms of fitness. In short, the precise entrainment of circadian rhythms to exact abiotic environmental cues requires further study in more systems and classes of organisms.

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## Tables and Figures.

**Figure 1.** Graph of the average of the total number of marmots visible over morning observation time. This graph also demonstrates average temperature over time for each side of the valley. The average of the total number of marmots visible was obtained by conducting a census every two minutes during the morning observation sessions, and then averaging the total number of marmots visible for each morning for each census. This was done for all of the western burrows, which are in pink, and also for all of the eastern burrows, which are in blue. Recorded temperatures were also averaged for each time they were recorded and plotted on the graph as a secondary axis. The green area represents the marmot thermoneutral zone.

**Figure 2.** Graph of the average number of marmots that were recorded during morning observation to be foraging or running over time, also in comparison to the average temperature over time. Average number of marmots foraging and running was calculated by recording the behaviors of each marmot during censuses that were conducted every two minutes during each observation session. These numbers were then averaged and the result plotted. Eastern burrows are delineated in blue and western burrows in pink. Temperatures were also recorded during observation sessions, then averaged and plotted as a secondary axis. The green area represents the marmot thermoneutral zone.

**Figure 3.** Graph of average total number of marmots visible over time in comparison with average temperature recorded during afternoon observation sessions. Average total number of marmots was calculated by recording total number of marmots visible during each census, which were conducted every two minutes during observation sessions, and then averaging these across all afternoons for eastern burrows and then all afternoons for western burrows. The same procedure was repeated for temperature, which was recorded throughout the afternoon and then averaged. Data taken from eastern burrows is delineated in blue, and western in pink.

**Figure 4.** Graph of average number of marmots running and foraging for each two minute census taken during observation according to time. Also in comparison with average temperature recorded per time during observation. Average number of marmots running and foraging calculated by recording each marmot's behavior during each census, then averaging the number running and foraging for each census time for all mornings for eastern burrows, in blue, and western burrows, in pink. Temperature calculated by recording during observation and then averaging across mornings for each side of the valley.

**Figure 5.** Behavioral ethogram for morning activity on western side of valley. Data obtained by recording behavior of each marmot during each census, which were conducted every two minutes during observation sessions. Behavioral data was then added across mornings and divided by total number of marmot sightings on the western side of the valley.

**Figure 6.** Behavioral ethogram for morning activity on eastern side of valley. Data collected through observation sessions, where a census was taken every two minutes, and behaviors of all visible marmots were recorded. Behavioral totals were then added across mornings per census time and divided by the total number of marmot sightings for all mornings on the eastern side of the valley.

Figure 1.

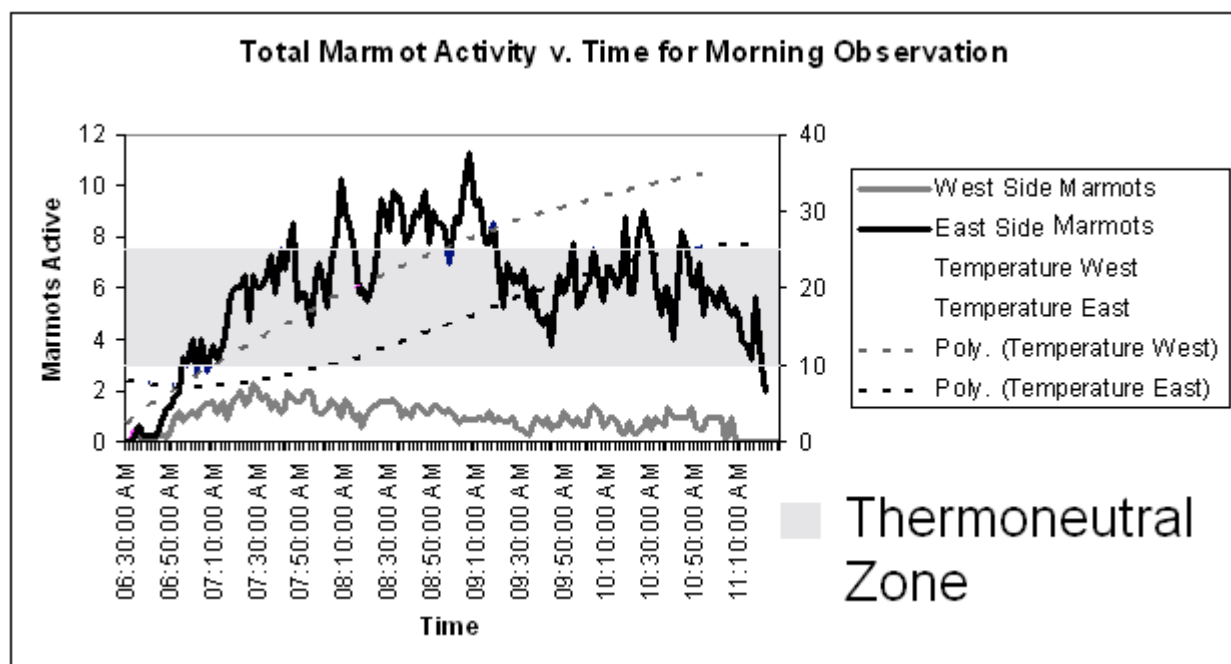


Figure 2.

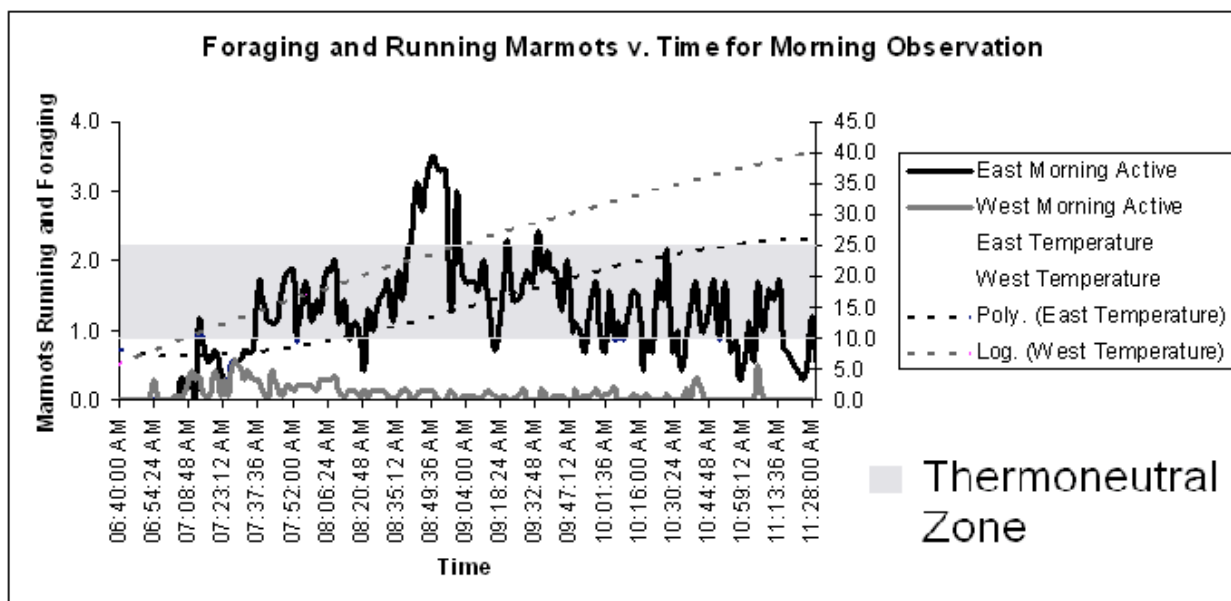


Figure 3.

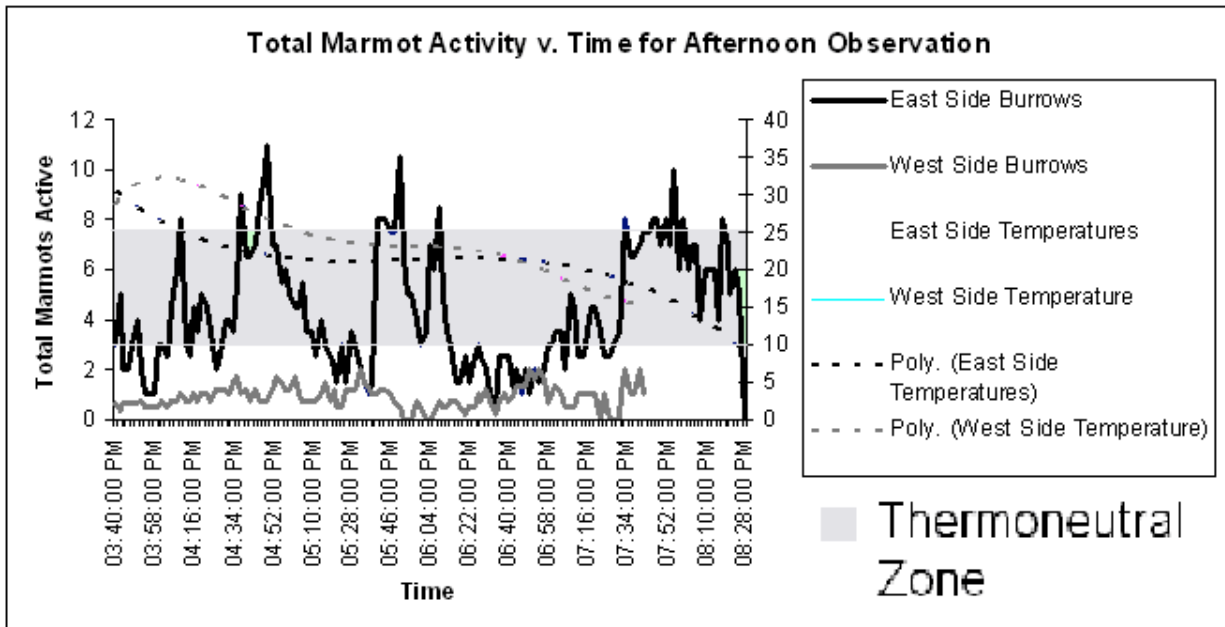


Figure 4.

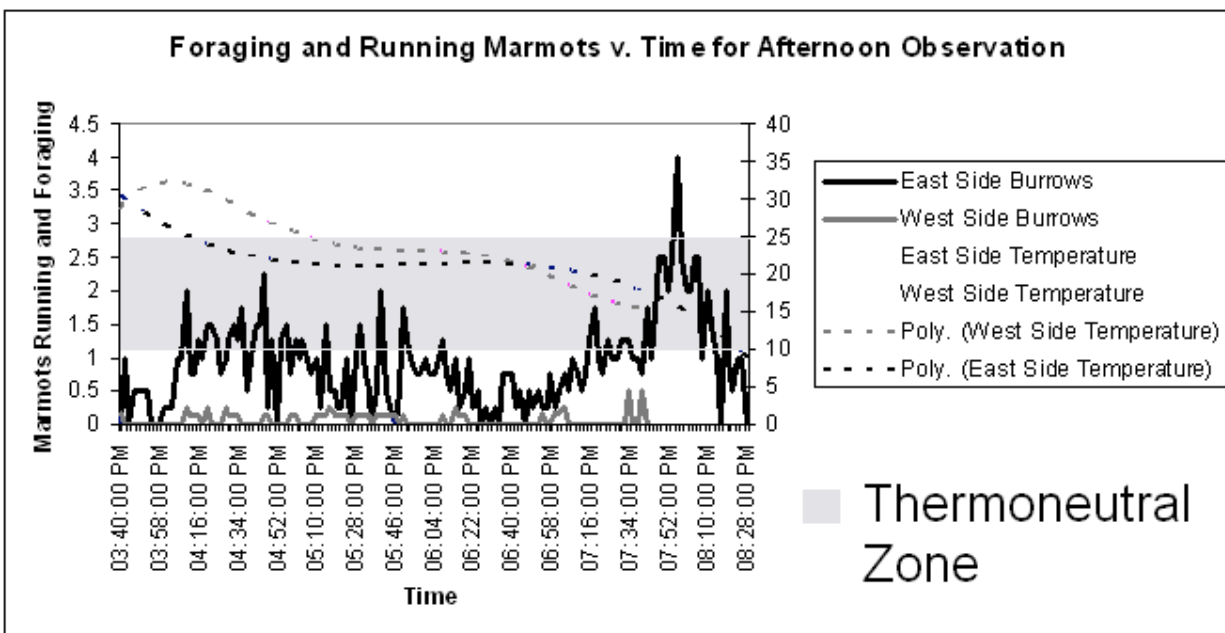


Figure 5.

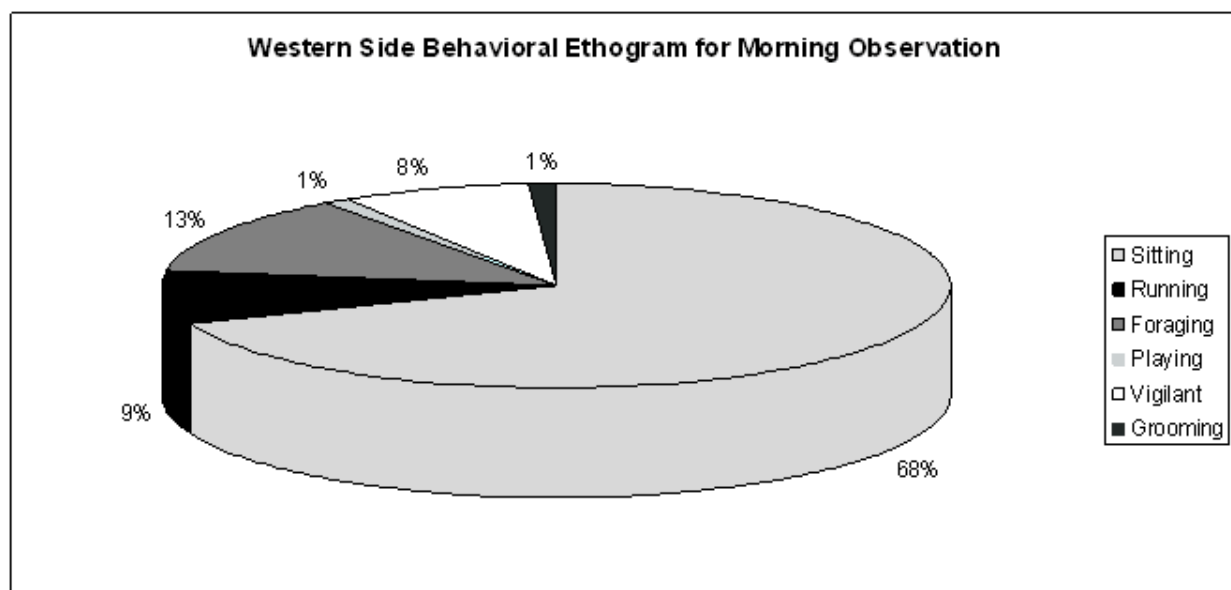


Figure 6.

