

**The Influence of Summer Precipitation and Temperature on Golden Mantled
Ground Squirrel Pup Foraging.**

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Abstract

Golden-mantled ground squirrels (GMGS) at the Rocky Mountain Biological Laboratory (RMBL) spend the majority of the year, from October to May, hibernating in order to save energy during the winter seasons in Gothic, Colorado. Once the winter season is over, the squirrels emerge from their burrows and spend spring and summer foraging in preparation for next winter. Foraging behavior is highly important during these months since food only starts to become available when snow melts, stimulating green vegetation growth. However, vegetation quality may depend on weather conditions: drier years may decrease vegetation quality, while wetter years may increase vegetation quality. Though behavioral flexibility is one of the most common modes of response across most mammal species, there is a lack of knowledge on how acute climate stress changes animals' foraging behavior. Behavioral flexibility is the ability of having diverse behavioral traits, which is important for species to adapt to any changes and survive in their environment. In conclusion, small mammals such as the golden-mantled ground squirrel, must constantly balance foraging and avoiding factors that increase mortality, including disadvantageous weather conditions. They can modify foraging patterns and overall daily activity when the weather changes (Stokes, 2001). Foraging activity was greatly affected by precipitation and temperatures in the month of July. With hotter temperatures more common in the future, I expect this effect to cause a negative shift in the pups foraging behavior, causing them to have to adapt in new ways.

Key Words: Golden-Mantled Ground Squirrel, Temperature, Precipitation, Behavioral Flexibility, Dry/Wet Years

Introduction

Foraging behavior changes are the most common mode of response across most mammal species, both large and small, but there is a lack of knowledge on whether acute climate stress poses a challenge to the animals' adaptive capacity (Beever et al., 2017). Climate change is the global or regional change in climate patterns over a long period of time. The global patterns of climate change are associated with widespread changes and are resulting in a rise in average temperatures. High-elevation ecosystems are highly sensitive and more vulnerable to climate change, and the expected increase in temperatures pose a major threat to range-restricted high-altitude species by shrinking the area of their suitable habitats (Dirnbock et al., 2011). These ecosystems are also threatened by the potential increase in aridity, which may cause more severe droughts and longer lasting heat waves (MacDonald et al., 2010). The most suitable habitats of terrestrial animals will continuously be altered by temperature and precipitation (Friggens et al., 2018). Although, we only know very little about how high-elevation species are changing their behavior in response to warmer and dryer conditions.

Golden-mantled ground squirrels (*Callospermophilus lateralis*, GMGS) are a high-elevation species. Once winter is over, the golden-mantled ground squirrels emerge from their burrows and spend the spring and summer months foraging. Juvenile foraging timing is highly important during these months since food is only available after snow melts, stimulating green vegetation growth. Since ground squirrels metabolize fat reserves that are built up during previous foraging seasons, it is highly important for GMGS squirrels to forage enough during the spring and summer months. Most of the fat that was stored is used during inter-torpor arousals when the squirrel warms up and has to stay warm for several hours at a time (Michener, 1992). High amounts of foraging will ensure enough fat storage levels to help with fitness and survival

for the winter (Wells et al., 2019). However, foraging behavior responses to changing weather conditions is complex. Foraging can be difficult in a wet year if precipitation is too high, causing the juvenile squirrels to stay underground for longer periods of time (Kneip et al., 2011). Staying in their burrows longer can cause them to miss out on or delay foraging time. In an early study, climatological data in relation to GMGS foraging was summarized, and it was found that average precipitation, or the central amount of rainfall, resulted in an unusually plentiful supply in vegetation. This allowed the ground squirrels to forage more and increase their body masses (Peterson, 1967). Foraging can be very difficult in a dry year, because a dryer year means less rain, which equals less vegetation growth (Sloat et al, 2015). In addition to dry years causing drought, dryer years during summers are also hotter, and golden-mantled ground squirrels are seriously affected by very high temperatures. Their activities are noticeably lower during warmer periods, so they tend to spend the hot part of the day in the cool protection of their burrows. Also, warmer periods have resulted in numerous deaths because the heat load became too much, causing their bodies to overheat (Peterson, 1967). This results in GMGS pups adopting a foraging strategy to reduce exposure to extreme heat conditions.

Animals adopt a foraging strategy that provides the most benefit (energy) for the lowest cost. It has been shown that resource availability also affects development once the juvenile is weaned, as the hypothalamic-pituitary-gonadal axis is sensitive to energetic factors. (Adkins-Regan, 2005). In a study on optimal traits and energy costs in determining foraging behavior, energy expenditure, predation risk, and other mortality factors such as weather conditions were studied. It was shown that increasing the magnitude of one cost decreases the sensitivity of optimal foraging strategy to that cost (Abrams, 1993). For example, the GMGS spends hotter days in its burrow to save energy and waits to forage when it is cooler in the day. This saves

them more energy at a lower cost than it would to forage on hotter days. The effect of optimal foraging behavior may be important for species living in strongly seasonal environments since growing seasons are shorter, which constrains foraging time and time to gain body mass. Drier conditions will affect foraging behavior by reducing activity due to warmer temperatures. If the GMGS pups have to spend more time underground to escape the heat, when they come back above ground, they will need to spend a higher percent time eating to make up for the lost time.

The golden-mantled ground squirrels (GMGS) at the Rocky Mountain Biological Laboratory (RMBL) spend the majority of the year hibernating in order to save energy during the winter season in Gothic, Colorado. This research project will help identify the direct influence of summer precipitation and temperature on golden mantled ground squirrel juvenile foraging, which is critical for survival over hibernation. This affects juvenile foraging in the long run if, when they are weaned, there is a lack of resources due to a short growing season or dryer year. I predict that wet and cool years will be better for the ground squirrels as dryer years and hotter temperatures will result in a decrease in above-ground foraging behavior in warmer summers.

Methods

Gothic, Colorado's golden-mantled ground squirrels were live-trapped, baited with black-oil sunflower seeds, salt, and peanut butter. Individuals were marked with numbered ear tags for permanent identification and a unique pattern of black dye. They were also weighed, determined as male or female, then released. This information was put into a database that has data starting in the year of 1995 at the Rocky Mountain Biological Laboratory. The databases from the past years were used to identify and recognize any changes in body mass, reproduction, survival, and dispersal. Locations of squirrels were mapped on the site's grid, and their behavioral interactions

were recorded. This recorded information was used for this project to identify changes in population of the golden-mantled ground squirrel and determine if increased/decreased foraging behavior was linked to changing weather conditions during dry versus wet periods throughout the summer. This helped identify the direct influence of July summer precipitation and temperature on golden mantled ground squirrel pup foraging.

In addition, I randomly selected and identified 10 different golden-mantled ground squirrel pups in each year from 2011- 2020 from the long-term data and activity budget along with the average July high temperature and July total rainfall. In each year and for each pup, I recorded all activity/behavior within that year. For precipitation, I measured the effect of it in two ways. I looked at dryer years defined as years with earlier snowmelt and July precipitation when pups were above ground. “Avg. July High Temp” “Total July Precipitation” were retrieved from the U.S. Climate Data in Crested Butte and Gothic Weather website, and I calculated the total or average for each column. Once my calculations were complete, I graphed the variables focused on in a scatterplot and compared them to my initial hypothesis.

Results

Total number of observations ranged from 223 to 1,392 per summer, and the total number of observations for July only ranged from 137 to 1175. Total number of all foraging observations ranged from 35 to 346, and the total number of foraging observations for July only ranged from 29 to 520. The average high July temperature for the years ranged from 66 degrees, which is considered very low, to 75.71 degrees. Total July precipitation ranged from 1.07 inches to 2.95 inches.

The two main factors in this research that affected foraging were precipitation, which includes early snowmelt, and July high temperatures. I initially predicted that wet years with increased rainfall would be better for the ground squirrels as dryer years and hotter temperatures will result in a decrease in body mass and species in warmer summers. Based on my data, graphs, and calculations, foraging had a slightly, positive relationship to July high temperatures (There was no relationship between average temperature and foraging [Residual standard error: 0.124 on 8 degrees of freedom, Multiple R-squared: 0.01933, Adjusted R-squared: -0.1032, F-statistic: 0.1577 on 1 and 8 DF, p-value: 0.7016]), and early snowmelt (There was a positive relationship, but the relationship was not significant. [Residual standard error: 0.1149 on 8 degrees of freedom, Multiple R-squared: 0.158, Adjusted R-squared: 0.05277, F-statistic: 1.501 on 1 and 8 DF, p-value: 0.2553]).

Golden-mantled ground squirrel pups spent a larger proportion of their time foraging in years with high average temperatures. In contrast, foraging had a negative relationship to rainfall (There was a negative relationship, but it was not significant [Residual standard error: 0.1207 on 8 degrees of freedom, Multiple R-squared: 0.07164, Adjusted R-squared: -0.0444, F-statistic: 0.6174 on 1 and 8 DF, p-value: 0.4547]). Pups spent a smaller proportion of their time foraging in years with more July rain. Though the overall relationship for foraging with high July temperature was positive, there were some years where foraging was lower due to increased temperatures, as well as there being higher foraging behaviors for some years due to high precipitation.

Discussions

The results did not fit my expectations, as I initially hypothesized that increased precipitation would have a positive relationship to pup foraging, while July high temperatures would have a negative relationship to pup foraging. (Peterson, 1967). I hypothesized that increased precipitation would increase pup foraging because increased precipitation results in increased vegetation, and pups should take advantage of high-quality vegetation to forage all they can in preparation for the upcoming winter season. Since the results were different from my expectations, I believe that the pups might be underground or participating in other activities during increased rainfall and aboveground during hotter temperatures. This may be due to the GMGS pups having to make up for foraging time lost during increased precipitation times.

Early Snowmelt dates relate to foraging as it gives an earlier start for the pups to forage, but it can also cause an increase in length and severity of a dry period or drought and rising air temperatures. If dry periods are too severe, plants can experience a strong fore summer drought and exhibit more water stress and lower rates of net ecosystem production (Sloat et al, 2015). This means that plants are not receiving the nutrients needed due to the drought, and as a result, the plants die off. In relation to foraging, this can cause decreased foraging because the plants no longer serve any nutritional value to the GMGS pups. Temperature and foraging relate as certain temperatures can either have a negative or positive impact on foraging behavior, as shown in my results.

In an early study on the American pika to understand the complex relationships between climate, vegetation, and foraging behavior of a climate-sensitive alpine animal, it was discovered that microclimate is the true driver affecting pikas' selective foraging behavior and plants simultaneously. In comparison to the golden-mantled ground squirrel, who's spring and summer

diet is highly important, the American pika's winter diet is highly important to winter survival and fitness for the spring breeding season, especially in high elevation areas where seasonality is extreme, ranging from hot, dry summer to freezing winters. Summer heat stress can limit vital storage time and harsh winters can limit forage availability (Cole, 2017).

In another earlier study on the yellow-necked mouse and the bank vole, it was discovered that temperature had a negative effect on the activity on both species, while rainfall positively influenced the yellow-necked mice foraging numbers but decreased the activity of the bank voles. Both species optimize their behavior due to weather conditions. It was observed that the reason precipitation positively affected the yellow-necked mice because precipitation can reduce prey detectability by helping mask the sound of movements and odors emitted by small mammals, such as the mice. On the other hand, where temperature had a negative effect on both species, it was observed that when different surroundings and body temperature increases, metabolic rate increases, too, to make up for heat loss. This results in low temperatures forcing rodents to forage at a much higher rate to make up for calories lost and for calories needed in order to maintain the proper body temperature (Wróbel, 2015). Overall, daily changes in activity are very important to adaptation because they help small mammals cope with variation predation and resource availability. These two factors are highly affected by weather, and small mammals have to constantly adapt and maintain behavioral flexibility and trade-offs between predation risk and foraging.

In conclusion, small mammals such as the golden-mantled ground squirrel, must constantly balance foraging and avoiding factors that increase mortality, including disadvantageous weather conditions. They can modify foraging patterns and overall daily activity when the weather changes (Stokes, 2001). Foraging activity was greatly affected by

precipitation and temperatures in the month of July. With dryer conditions more common in the future, I expect this effect to cause a negative shift in the pups foraging behavior, causing them to have to adapt in new ways. For example, if dryer conditions do persist, the pups may have to switch their foraging times and forage more during the early mornings or late afternoons, but a risk is that switching one behavior with another may increase the risks of encountering one or more of their predators. To reach an optimal balance and conclusion for further investigation and management plans, looking at more years, behavior/activity, GMGS pup body mass, and recording the time that individual pups are above and below ground will be beneficial. Determining this information can be used to identify the relationship between foraging time and mass gain, if the pups are gaining enough mass to survive the winter seasons, and the success rate of future golden mantled ground squirrels at the Rocky Mountain Biological Laboratory.

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Tables and Figures

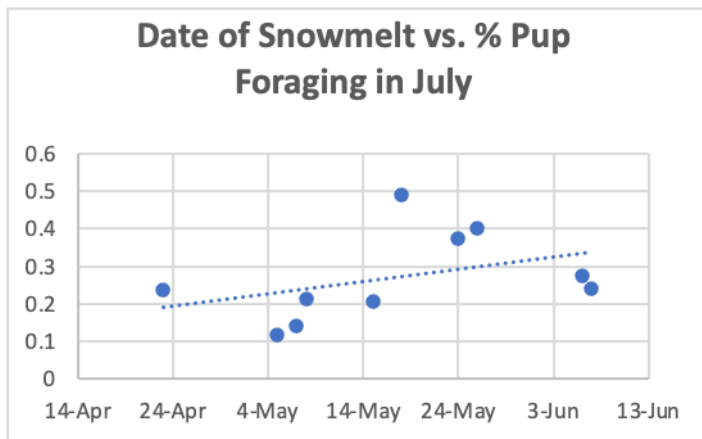


Figure 2. Date of snowmelt versus % pup foraging in July. Values above the slope represent increased foraging behavior. Values below the slope represent decreased foraging behavior. Points indicate observed values. The solid line represents the overall relationship of date of snowmelt and % foraging, which shows a slightly positive relation. Interpretation: When it comes to snowmelt, it is about time, instead of the amount of food. [Residual standard error: 0.1149 on 8 degrees of freedom, Multiple R-squared: 0.158, Adjusted R-squared: 0.05277, F-statistic: 1.501 on 1 and 8 DF, p-value: 0.2553]

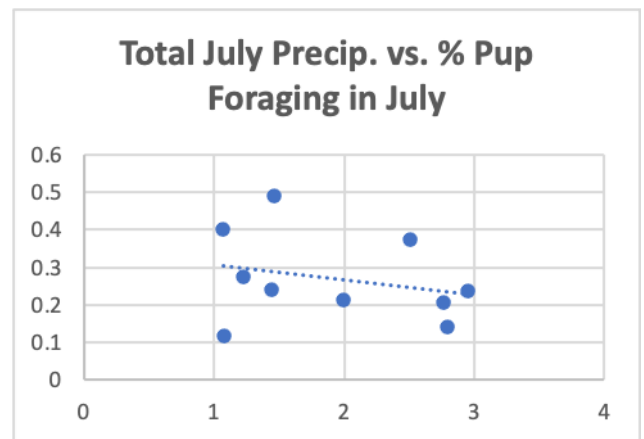


Figure 3. Total July Precip versus % pup foraging in July. Values above the slope represent increased foraging behavior. Values below the slope represent decreased foraging behavior. Points indicate observed values. The solid line represents the overall relationship of date of snowmelt and % foraging, which shows a negative relation. [Residual standard error: 0.1207 on 8 degrees of freedom, Multiple R-squared: 0.07164, Adjusted R-squared: -0.0444, F-statistic: 0.6174 on 1 and 8 DF, p-value: 0.4547]

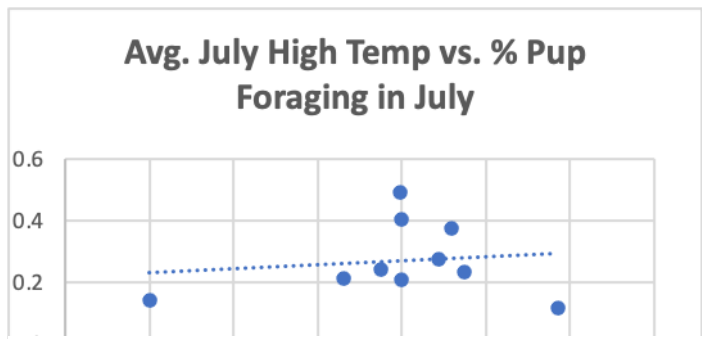


Figure 4. Average July High Temp versus % pup foraging in July. Values above the slope represent increased foraging behavior. Values below the slope represent decreased foraging behavior. Points indicate observed values. The solid line represents the overall relationship of date of snowmelt and % foraging, which shows a slightly positive relation. [Residual standard error: 0.124 on 8 degrees of freedom, Multiple R-squared: 0.01933, Adjusted R-squared: -0.1032, F-statistic: 0.1577 on 1 and 8 DF, p-value: 0.7016]