

Habitat Quality Affecting the Body Mass of Golden-mantled Ground Squirrels

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August 8, 2022

Abstract

In conservation, it is vital to understand how organisms use their habitat and what constitutes high quality habitat. This has become increasingly urgent in ecosystems impacted by direct or indirect human disturbances such as habitat loss or climate change. High elevation ecosystems are particularly vulnerable to climate change, putting pressure on the organisms in these systems. However, local and micro-scale heterogeneity across the landscape potentially offers a buffer against climate change by creating small-scale differences in habitat quality. Small hibernating mammals such as the golden-mantled ground squirrel (*Callospermophilus lateralis*) may leverage microclimates to cope the effects of a warming climate. This study used drone imagery to collect fine scale data on factors contributing to habitat quality within home ranges of golden-mantled ground squirrels in the vicinity of Rocky Mountain Biological Laboratory. Thermal variation, food resources, and the abundance of perches for individual home ranges were compared to body mass, which is a strong indicator of survival and fecundity. The goal of this study is to further our understanding of how local differences in the landscape enhance habitat quality for golden-mantled ground squirrels. No significant trends were found when the average temperature, abundance of food resources, or number of perches were compared to mean body mass. However, further analysis and the comparison to other methods of assessing habitat effects on fitness may provide insight the role of habitat quality in this system.

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Introduction

Climate change is altering the ecology of high-elevation ecosystems, changing hibernating mammals foraging behavior and forage quality (Eastman et al., 2012; Sloat et al., 2015). Rising temperatures impact how small mammals thermoregulate. For example, the American Pika is experiencing climate-related declines but has shown phenotypic plasticity in response to increasing temperatures. Pikas thermoregulate by spending more time in their burrows and in some cases using forested habitat instead of their typical broken-rock habitat (Beever et al., 2017). Pikas were also observed to exhibit this thermoregulation behavior at lower elevations, which tend to be warmer (Beever et al., 2017). Marmots (*Marmota*) also display phenotypic plasticity in their burrow choice, taking advantage of a variety of landcovers, and use their burrows to reduce heat stress by avoiding the surface during the hotter parts of the day. (Armitage, 2013). Arctic Ground Squirrels (*Spermophilus parryi*) also exhibit this behavior in response to heat stress (Long et al., 2005). Golden-mantled ground squirrel use this strategy that is common in other ground squirrels.

However, there may be a trade-off associated with decreasing above-ground activity. Increased below-ground activity reduces foraging time which could have an impact on body mass. Body mass is related to the survival and fecundity of ground squirrels (Sauer & Slade, 1987). Higher temperatures could have an impact on food availability as well as a decrease in foraging time in hibernating mammals (Wells et al., 2022). High elevation ecosystems, such as our study site in Gothic, CO, are experiencing faster warming than the global average (Ipcc, 2022). As a result of accelerated warming, we may be able to see the effects of decreased foraging time in body mass explained by local thermal variation. Variation local temperature may have a buffering effect against heat stress in areas with cooler microclimates. If golden-

mantled ground squirrels are able to take advantage of cooler areas of their home range they may increase their above-ground activity, increasing foraging time and resulting in higher body masses.

Additionally, the abundance of food resources is related to the foraging quality within a home range, this could obscure any trends between temperature and body mass. *Taraxacum officinale* (common dandelion) is an important food resource for Golden-mantled ground squirrels. *T. officinale* was determined to account for 80% of the golden-mantled ground squirrel diet at the Rocky Mountain Biological Laboratory from June to August (Carleton, 1966). Variation in *Taraxacum* abundance as well as other food resources may cause changes in body mass that is not explained by the time spent foraging.

In addition to the abundance of resources the accessibility of resources may also cause drive differences in body mass. Perches are structures above the vegetation height are used to spot predators while foraging. Insufficient or low-quality perches may lead to a decrease in forage quality for an individual's home range. If a section of habitat has an abundance of food resources but a low abundance of perches, those food resources may not be utilized. In addition to the number of perches, the distance from the perch to a burrow or the height of surrounding vegetation affects foraging quality. In Daurian ground squirrels (*Spermophilus dauricus*) flight initiation distance (FID) increased when using perches further from a burrow or perches with tall surrounding vegetation (Shuai et al., 2019). This could indicate the quality of a perch has an impact. However, there may be no effect on fitness if golden-mantled ground squirrels also increase flight initiation distance on this perch. If this is not observed in golden-mantled ground squirrel behavior perch quality may also affect food resource accessibility. The variation of the quality and number of perches in a home range may lead to an effect on fitness.

As anthropogenic changes to landscapes accumulate, microrefugia and local variation may allow organisms to cope with environmental pressures. This project uses drone imagery to examine thermal microclimate variation, dandelion abundance, vegetation landcover, perch availability impacts the body mass of adult female golden-mantled ground squirrels. Detailed drone imagery allows us to examine local variation within individual home ranges for each golden-mantled ground squirrel. Using drone imagery allows data collection at a fine scale that would not be feasible by hand. This allows detailed examination of variation between various home ranges. Taking this approach will allow us to precisely examine the magnitude of resource abundance and temperature on body mass. Understanding how different local variation affects body mass in golden-mantled ground squirrels will help build towards a greater understanding of how local variation impacts other small hibernating mammals.

Hypotheses

H1: Warmer home ranges are expected to be negatively correlated with body mass if there is a tradeoff between time spent foraging and time spent in the burrow to thermoregulate.

H2: Increased dandelion abundance is expected to be positively correlated with body mass.

H3: Increased vegetation cover is expected to be positively correlated with body mass.

H4: Perch abundance is expected to be positively correlative with body mass.

Methods

The study site was in the Gothic, Colorado at the Rocky Mountain Biological Laboratory (38.958611, -106.987778). Observational golden-mantled ground squirrel data studied squirrels within the Gothic townsite. This data has been used to study a wide range of topics such as

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H1: Warmer home ranges are expected to be negatively correlated with body mass.

H2:....

maternal survival cost (Kanaziz et al., 2022), Behavior and Spatial dynamics (Aliperti, 2020), and early reproduction (Wells & Van Vuren, 2018). The site is a subalpine meadow surrounded by adjacent meadows, aspen forest, and spruce-fir forest.

This study was conducted using data from multispectral and thermal sensors (Micasense Altum) mounted on an uncrewed aircraft system (DJI m300), from Dr. Ian Breckheimer, observational data from 2019 to 2021 on golden-mantled ground squirrels, from Dr. Caitlin Wells, and coordinates corresponding to observed locations of the golden mantled ground squirrels from Jaclyn Aliperti. All the components of this study rely on body mass data collected in from 2019 to 2021. Minimum convex polygons (MCPs) of some ranges were constructed from observational location data (Wells & Van Vuren, 2018), which corresponds to a coordinate point (Aliperti, 2021), for each adult female each year. MPCs using 55% and 85% of the observational data for each individual was created using R studios using the adehabiatHR package. 88 sets of home ranges were created. Of the 88 home ranges, 44 total home ranges consisting of 85% MCPs and 44 home ranges consisting of 55% MCPs, using observational data from 2019 to 2022. This effectively creates 44 replicates for each set of MCPs. To create core home ranges 55% of the observational data was used and to create total home ranges 85% of the data was used to exclude outliers. Outliers were identified by creating line graph of the percentage of the data incorporated and the area of each individual MPCs. In QGIS the zonal statistics tool to was used to quantify the vegetation cover, dandelion abundance, mean temperature, area, and the number of perches within the 55% and 85% MCPs for each individual.

The first component of the study examined the relationship between microclimate temperature and body mass. Using a GIS program (QGIS), the temperature microclimate as the variation within radiometric temperature recorded on 07/07/2021, 07/27, 08/24/21 within each

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home range was summarized. Using zonal statistics in QGIS will allow the mean temperature in each home range to be calculated. Buildings and cars were excluded from the raster file by using an existing classification raster file created by Dr. Ian Breckheimer. Buildings and cars were excluded to reflect actual thermal conditions experienced by golden-mantled ground squirrels,

The second component compared body mass to the percent of vegetation cover in an individual's home range. In QGIS, zonal statistics was used to calculate vegetation cover in home ranges. Vegetation cover was calculated by grouping the landcover into a binary mosaic of vegetated or non-vegetated surface. The mean of the land cover shows the percent landcover of vegetation in each home range.

The third component quantified the abundance of dandelions within an individual's home range using drone imagery, zonal statics in QGIS, and on-ground surveys. A one-by-one meter quadrat was used to count the number of ten-by-ten cm squares with 50% or greater dandelions cover to approximate the percent of dandelion cover. Data was taken from three quadrants in each home range, corresponding to low, medium, and high dandelion abundance. The time the survey began, the time it ended, the number of squares with 50% or more dandelion cover, and the gird square location was recorded for each plot. Each corner of the plot was recorded by an EMLID Reach RS2 GPS system, which recorded position with approximately 1.5 cm spatial accuracy. In QGIS, a set of 188 training points was heads-up digitized by identifying dandelion flowers in ~1cm resolution drone imagery collected on June 15th, 2021. These points were then combined with points previously digitized as part of a vegetation mapping effort (Breckheimer et al. in prep) to form a training set for classification. An AI generated binary map of dandelion map was used to estimate the percent of land of dandelion abundance. The error between the observed and estimated dandelion cover was calculated using the root mean squared error

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(RMSE). This is to account for error in the drone imagery, may come from shading, other vegetation cover, AI identification of dandelions

The fourth component quantified the number of perches in each home ranging using height measurements from drone imagery. Buildings and cars were excluded from the raster file by using an existing classification raster file created by Dr. Ian Breckheimer. Perch height was calculated by subtracting a digital elevation model raster from a digital surface model raster. In QGIS the tool r.neighbors was used to transform a canopy height model to create a raster layer with average canopy height in a 13 meter radius. The digital elevation model, digital surface model, and canopy height model were created by Dr. Ian Breckheimer. A conditional raster algebra statement requiring perch height to be greater than the 13m radius average canopy height model created a raster layer of binary map depicting perch or non-perch values. This raster layer was converted into a polygon layer to create a map of perches as single objects. These polygons were then converted into points that were counted within each home range to calculate the number of perches in each habitat. The number of perches were counted using zonal statistics in QGIS

All the data from the experiment was be analyzed using multiple linear regressions to determine the direction and significance of any trends in the data. The independent variables respectively are mean temperature, percent of dandelion cover, percent of vegetation cover, and the number of perches. The dependent variable is mean body mass for each individual. .

Results

The area of the total home ranges ranged from 0.0480 km^2 to 1.09 km^2 with a mean of 0.286 km^2 . The area of the core home ranges varied from 0.00276 km^2 to 0.709 km^2 , with

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a mean of 0.116 km^2 . Mean body mass for each individual ground squirrel ranged from 173.25 g to 305.3 g, with an average mean body mass of 223 g and followed a normal distribution. The percent of dandelion cover in the total home ranges ranged from 1.834% to 13.29%, with a mean of 5.953%. The percent of dandelion cover in core home ranges (55% MCPs) varied from 1.834% to 15.45% of land cover in the home range with a mean of 6.416%. The average temperature of each home ranged varied from a temperature of 13.8 C° to 25.1 C° with a mean of 25.1 C° in the total home ranges and from 12.37364 C° to 25.1166 C° , with a mean of 21.1 C° in the core home ranges. The percent of vegetation cover ranged from 32.14% to 87.02%, with a mean of 63.80% in the total home ranges and from 22.30% to 96.55% with a mean of 63.61% in the core home ranges. The number of perches in the ranged from 37 to 6,799 perches with a mean of 1217 perches in total home ranges and ranged from 3 to 5087 perches with a mean of 563 perches in the core home ranges.

Using a multiple linear regression, area, dandelion cover, vegetation cover, average temperature, and the number of perches in each home range were compared to mean body mass. The results revealed that there was no not statistically significant relationship between any other variables and mean average body mass in the total home ranges (Table 1). The effect of dandelion abundance on mean body mass had a p value of 0.739926 in the 85% MCPs. The effect of vegetation land cover on mean body mass had a p value of 0.351860 in the 85% MCPs. The effect of average temperature on mean body mass had a p value of 0.883963 in the 85% MCPs. The effect of number of perches on mean body mass had a p value of 0.573807 in the 85% MCPs. The effect of home range area on mean body mass had a p value of 0.317487 in the 85% MCPs.

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Table 1. The summary statistic for 85% MCPs for each individual home range

	Estimate	Std. Error	T value	Pr(> t)
Area	54.7	54.0	1.01	0.317
Percent of Dandelion Land Cover	-72.4	216	-0.334	0.739
Percent of Vegetation Cover	-41.1	43.6	-0.943	0.351
Average Temperature	-0.00318	0.0216	-0.147	0.883
Number of Perches	-0.00561	0.00990	-0.567	0.573

The results show that there is no statistically significant relationship between any of the variables and mean body mass (Table 2.). The effect of dandelion abundance on mean body mass had a p value of 0.232 in the 55% MCPs. The effect of vegetation land cover on mean body mass had a p value of 0.898 in the 55% MCPs. The effect of average temperature on mean body mass had a p value of 0.530 in the 55% MCPs. The effect of number of perches on mean body mass had a p value of 0.864 in the 55% MCPs.

Table 2. The summary statistics for 55% MCPs

	Estimate	Std. Error	T value	Pr(> t)
Area	4.41e+01	8.06e+01	0.547	0.587
Percent of Dandelion Land Cover	-2.24e+02	1.84e+02	-1.21	0.232
Percent of Vegetation Cover	-4.02e+00	3.11e+01	-0.129	0.898
Average Temperature	-1.24e-02	1.97e-02	-0.634	0.530
Number of Perches	2.083-03	1.21e-02	0.172	0.864

Discussion

Despite the lack significance in each variable predicting body mass the results can provide insight into how this study system operates. If the area of an individual's home range has no effect on body mass the distribution of body mass may be explained by variation in habitat quality. Individuals could be occupying smaller home ranges with higher habitat quality resulting in similar body masses as seen in the normal distribution of mean body mass. However, in this study we did not see a significant effect on body mass from any of measures of habitat quality. If this holds true after further analysis, it will indicate that that other factors are influencing habitat quality or habitat quality is not the main driver of body mass in this study system. It may be the case that there is not significant variation between habitats to influence body mass. If this is true, we would expect that there is an abundance of dandelions and other food resource within each habitat, not limiting body mass in any case. We would also expect that there are enough quality perches within a habitat to the extent that food resources are not limited by food resources. The

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results of this study also support the idea that body mass is not impacted by a trade off between time spent foraging and time spent **thermoregulating**.

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If habitat quality is not the main driver of body mass other factors such as reproductive status, litter size, pup body mass, or weight held over winter. Our study did not account for litter size or reproductive status, which created noise in that data and may have obscured trends related to habitat quality. Litter size and pup body mass influences the body mass of adult females through parental investment. Reproductive status may also change how body mass is reflected in golden-mantled ground squirrels due to a change in hormones in an individual. Weight held over winter may also influence **growth rate, maximum body mass, and amount of parental investment**. Individuals with starting the active season with greater mass may have an advantage over other individuals that held on to less of their weight. If habitat quality is not significantly impacting body mass, it is likely that these effects are driving differences in body mass. These factors were not incorporated in this study, however if they are accounted for in a future study it may reveal trends that were not apparent here.

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Aside from the factors listed previously there may be other reasons no clear trends were able to observe in this study. **The sample size was too small to reveal trends**, only 44 unique home ranges were incorporated into this study. However, incorporating data spatial data from trap logs in 2020 and 2021 would increase the number of individuals that meet the required 30 observations to be included in the study. In addition, data from 2022 and 2018 could be added to the study to increase the sample size. An increased sample size will drastically increase the likelihood of revealing any underlying trends.

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The perch data may also have noise obscuring trends. The remote sensing method may incorporate perches that are not large enough to support a golden-mantled ground squirrel. The

perch data collected by remote sensing could be compared to perch data that was taken on the ground by Autumn Dorr in 2022 to identify the accuracy of the remote sensing data. The perch data also could be more sensitive to perch quality, the current data only includes perches above the average vegetation height with in a 13-meter radius. However, vegetation height around the perches may impacts the quality of the perch. (Shuai et al., 2019) In addition to this analyzing the amount of land cover with sufficient perches rather than the number of perches in an individual home ranges may provide better insight to the perch quality of the entire home range. Directly measuring the time spent foraging for each individual would be a better metric to investigate whether temperature of a home range creates a trade off between time spent thermoregulating and time spent foraging. Examining these effects at different home range extents by creating MCPs that incorporate different amounts of observational data may impact results.

Area has no effect on body mass which would indicate that habitat quality varies between home ranges. But produces no effect on body mass since it is accounted for by area. When controlling for area there was still no effect on body mass. Also account of for age, which may account for experience. The billy bar Community Center (bbcc) may be having an effect of as a human shield which could explain the size of territories in that the territory is aggressively defended to exclude other from that benefit. The bbcc also has a high number of perches, and an abundance of human food. It would be interesting to compare the distribution of home ranges before and after the bbcc was built. Vegetation height regardless of perch height may also impact perch quality. In QGIS the binary vegetation map could be used to examine perches in vegetated vs no vegetated areas and the vegetation height map could be used to examine perches in stratified vegetation heights. The way to quantity perches needs to be severely refined to exclude non-viable perches. The distribution rather than count also ought to be accounted for. If home

range size is density dependent, we may expect to see that home range size is driven by behavior and personality rather than habitat quality.

Further analysis of this study could provide information in how golden-mantled ground squirrel use space and what factors are relevant to their fitness. Understanding these environmental factors would help further knowledge of how other small mammals use space and guide conservation research. This project also relies on drone imagery, which opens the possibility of utilizing drones to identify local features across the landscape that are critical for conservation goals. This application would allow land manager to identify large areas of land that would be beneficial for to conserve as well as small local areas that could be targeted. Targeting specific locations may help balance conservation goal and recreational use of public land. home range size is mainly influenced by the personality of individual ground squirrels. This would support a previous study that found that bolder individuals had larger core home ranges (Aliperti) Aggressive individuals also were found to have a greater number of perches in their home ranges (Aliperti) This is evidence that at least on measure of habitat quality is related to personality.

Acknowledgements

I would like to thank Dr. Ian Breckheimer for mentoring me through out this project. His guidance enabled me to take on new challenges and learn new skills that will enable me to pursue a career in research. I would also like to thank Dr. Caitlin Wells for guidance in this project and providing the necessary data. I would like to express gratitude to Dr. Jaclyn Aliperti for sharing data that made is study possible. I am grateful to the Rocky Mountain Biological Laboratory and Colorado State University for funding my research experience this summer. This opportunity the most value experience in my professional career. This study was conducted on Ute land and while it is important to bring attention to this fact, it is exponentially more import to remember that land acknowledgements are not a solution, nor do they represent justice. I would like to propose the idea the readers of this paper. The Rocky Mountain Biological Laboratory should have an outreach program, facilitated by members of the Ute tribes, to give Ute children more opportunities to pursue a career in research.

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Appendix I

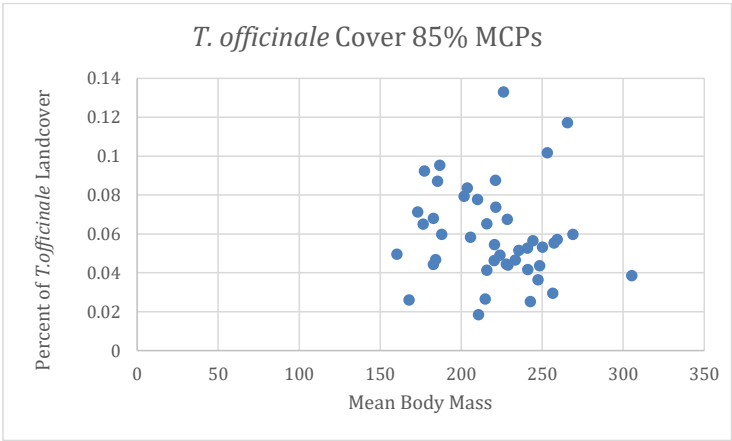


Figure 1. The effect of percent of dandelion cover in an individual's home range on an individual's mean body mass in 85% MCPs

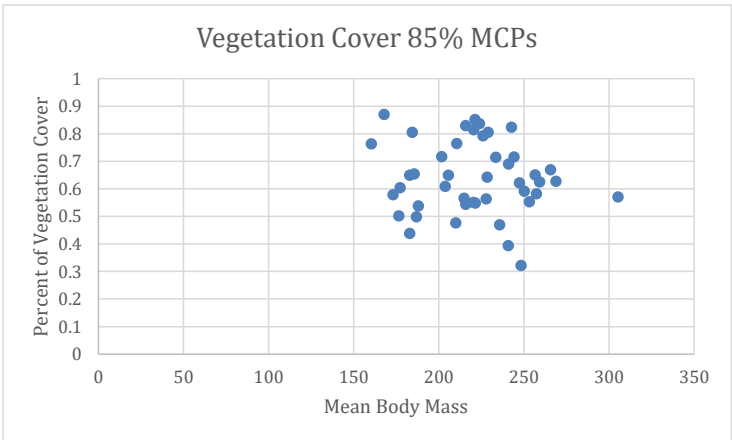


Figure 2. The effect of percent of vegetation cover in an individual's home range on an individual's mean body mass in 85% MCPs

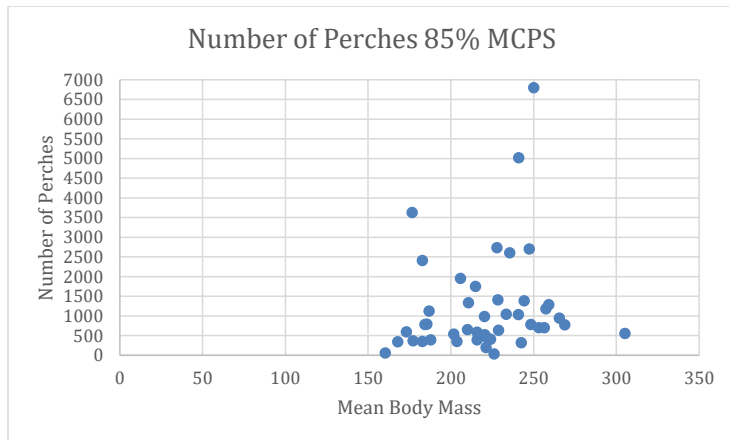


Figure 3. The effect of the number of perches in an individual's home range on an individual's mean body mass in 85% MCPs

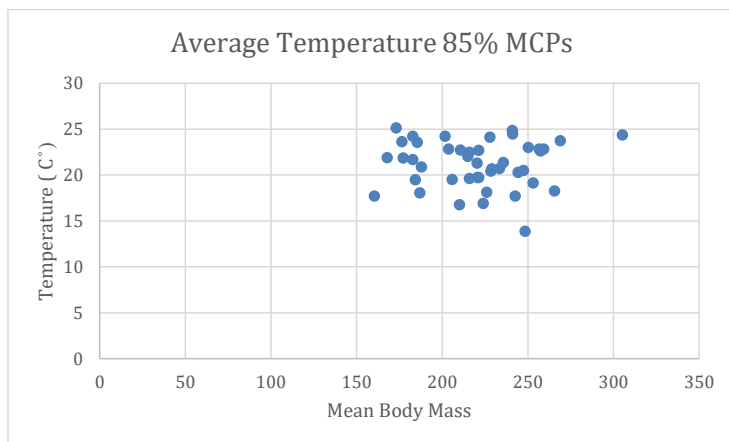


Figure 4. The effect of average temperature in an individual's home range on an individual's mean body mass in 85% MCPs

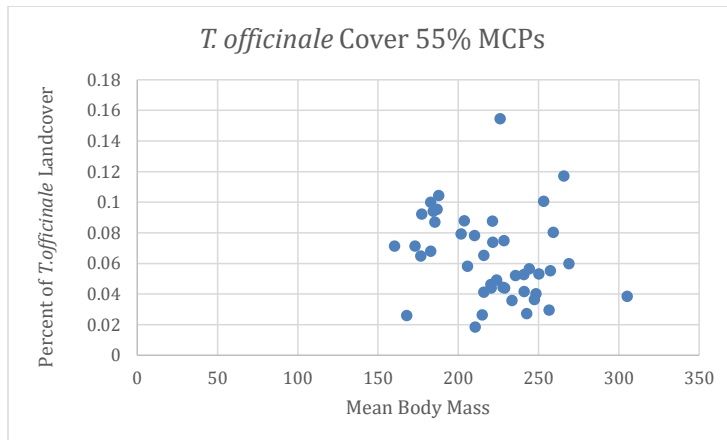


Figure 5. The effect of percent of dandelion cover in an individual's home range on an individual's mean body mass in 55% MCPs

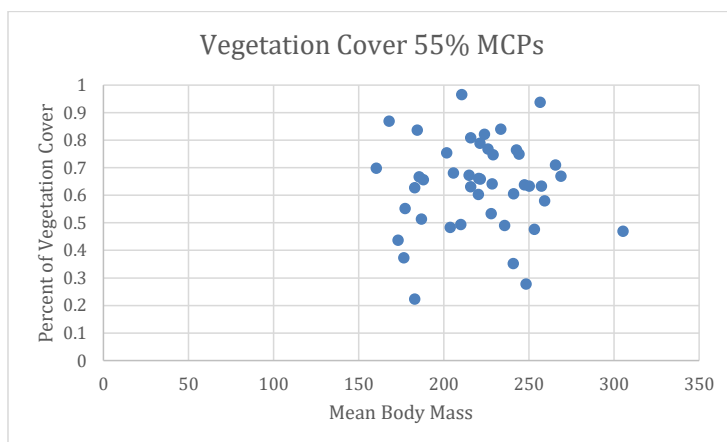


Figure 6. The effect of percent of vegetation cover in an individual's home range on an individual's mean body mass in 55% MCPs

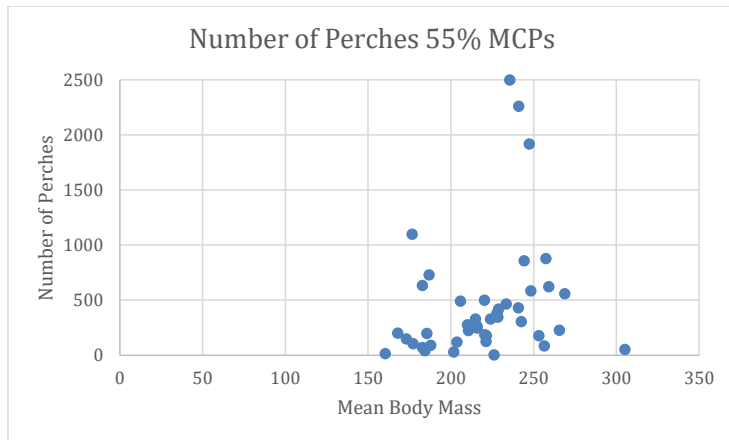


Figure 7. The effect of the number of perches in an individual's home range on an individual's mean body mass in 55% MCPs

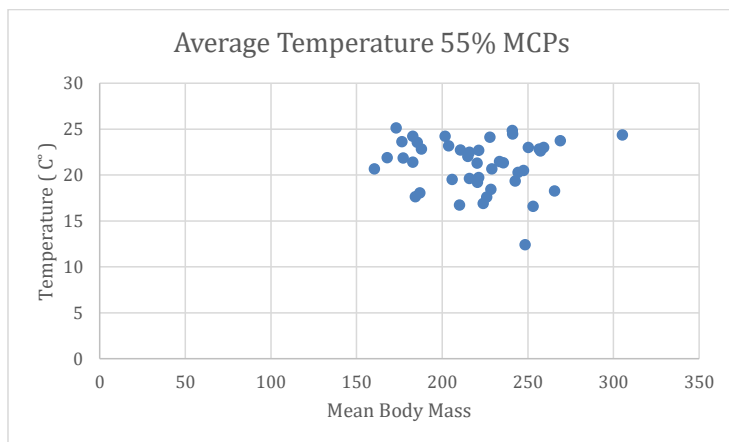


Figure 8. The effect of average temperature in an individual's home range on an individual's mean body mass in 55% MCPs

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