Final Report

Distribution and habitat selection by the Peñasco least chipmunk (*Neotamias minimus atristriatus*)

Submitted to:
New Mexico Department of Game and Fish Share with Wildlife Program

Fiona E. McKibben and Jennifer K. Frey
Department of Fish, Wildlife and Conservation Ecology
New Mexico State University

24 March 2020

I. Executive Summary

The Peñasco least chipmunk (*Neotamias minimus atristriatus*) is listed as endangered by New Mexico and is a candidate for federal listing under the Endangered Species Act (ESA). It is only known to persist in the Sierra Blanca subrange of the Sacramento Mountains, New Mexico. Basic data on the distribution and habitat associations of *N. m. atristriatus* are necessary to develop effective conservation and management plans. The overall goal of this study was to critically evaluate the distribution, habitat selection, and ecological interactions of this state endangered species. We investigated habitat selection at three spatial scales using occupancy modeling based on camera trap data to describe the geographical range of the subspecies, and resource selection functions based on radio telemetry movement data to describe the selection of home range locations and the selection of patches within a home range. To inform the occupancy study, we conducted a controlled experiment to test if *N. m. atristriatus* could be distinguished from *N. canipes* based on photographs. We deployed camera traps at 239 locations throughout the Sierra Blanca subrange, stratified by land cover type and elevation. We radio-tracked 16 chipmunks at the Lookout Mountain-Ice Springs study area. The identification experiment revealed that the two species of chipmunks could be identified on basis of photographs. The occupancy analysis is currently underway. At the macrohabitat scale (i.e., selection of locations of home ranges), *N. m. atristriatus* selected areas with trees scattered within a herbaceous matrix, near shrubs and rocks, on sunny sites with relatively flat terrain, and far from montane coniferous forest biotic community and burnt forest. These conditions were patchy and restricted in area, suggesting the subpopulation may be small. At the microhabitat scale (i.e., selection of patches within a home range), *N. m. atristriatus* selected areas with large diameter Engelmann's spruce (*Picea engelmannii*) trees, boulders, gooseberry, and vertical cover, and avoided patches of high herbaceous cover. These results suggest that *N. m. atristriatus* is a habitat specialist and that conservation of the Lookout Mountain-Ice Springs subpopulation should focus on maintaining old growth *P. engelmannii* forest and a shrub understory.

Contents

List of Tables

List of Figures

II. Project Introduction

The Peñasco least chipmunk (*Neotamias minimus atristriatus*) is a candidate for federal listing under the Endangered Species Act (ESA) and is only known to persist in the Sierra Blanca subrange of the Sacramento Mountains, New Mexico. The New Mexico Department of Game and Fish (NMDGF) considers it threatened by habitat alteration, drought, wildfire, and potential competition (NMDGF 2016). In 2011, the US Fish and Wildlife Service (USFWS) was petitioned to list this chipmunk under the Endangered Species Act and in 2012 the USFWS determined that listing of the species was warranted but precluded and designated it a Candidate with high magnitude threats (USFWS 2014). The subspecies has not been verified in the southern Sacramento Mountains subrange since 1966, despite intensive sampling (Hope and Frey 2000, Frey and Boykin 2007, Wampler et al. 2008, Frey and Hays 2017). The Sierra Blanca population was verified in 1998, 2000, 2016, and 2018 (Ortiz 1999, Hope and Frey 2000, Frey and Hays 2017, Frey and McKibben 2018).

Basic data on the distribution and habitat associations of *N. m. atristriatus* are necessary to develop effective conservation and management plans. Managers must understand where the species occurs, where it is predicted to occur, and key habitat characteristics to understand and manage for threats to the species and its habitat. The overall goal of the current study is to critically evaluate the distribution, habitat selection, and ecological interactions of this state endangered species using occupancy modeling techniques, radio telemetry, and resource selection functions.

Animals select habitat differently at different spatial scales, and it is important to consider scale when designing habitat selection studies. Spatial scale is determined by both grain and extent; grain is defined as the finest spatial resolution measured and extent is the overall size of the landscape examined (Ciarniello et al 2007). Changing the grain or the extent of investigation can result in changes in the magnitude and even in the direction of selection. Johnson (1980) described four hierarchical scales of habitat selection: physical or geographical range (first order); macrohabitat or selection of home range (second order); microhabitat or use of habitat within a home range (third order); and selection of specific components such as food items (fourth order). O'Neill (1989) further proposed that studies should ideally consider three nested scales of selection assuming that selection is constrained by the scale above and further explained by the scale below. This allows researchers to detect how selection is affected by scale.

Although our investigation does not fall neatly into Johnson's orders of selection, we did investigate habitat selection at three spatial scales. We used occupancy modeling to describe the distribution of the subspecies within a portion of Sierra Blanca (analogous to Johnson's first order of selection), and resource selection functions based on radio telemetry movement data to describe the selection of home range locations and the selection of patches within a home range (analogous to Johnson's second and third orders of selection, respectively).

III. Occupancy study

A. Introduction

Occupancy modeling is a likelihood-based method for estimating probability of occupancy when detection probability is <1. Covariates can be modeled to account for differences in detection probability and probability of occupancy between surveys and between sites. Covariates for occupancy can identify key habitat associations, important for managers and policy makers. Perkins-Taylor and Frey (2018) used occupancy analysis to model the distribution and habitat associations of the Oscura Mountains Colorado chipmunk (*Neotamias quadrivittatus oscuraensis*), a rare subspecies of the Colorado chipmunk.

N. m. atristriatus is only known to persist in the Sierra Blanca area of the Sacramento Mountains, primarily within the White Mountains Wilderness Area, a high elevation area, accessible only via backcountry trails. At this remote site, traditional trapping methods prove inefficient or ineffective. Live traps require frequent monitoring and are traditionally set in grids or trap lines of hundreds of traps at each survey site. The logistics of transporting hundreds of traps into a wilderness area and monitoring traps appropriately would limit the total number of sites surveyed. Live trapping in high mountains can also present ethical concerns about leaving animals in traps when researchers must vacate a location unexpectedly for human safety in the face of extreme weather.

Camera traps provide an alternative method well-suited to occupancy analysis, which only requires detection/non-detection data. Camera traps have been used successfully for occupancy analysis in studies of large mammals such as sun bears and brown hyenas (Linkie et al. 2007, Thorn et al. 2008). De Bondi et al (2010) directly compared live trapping to camera trapping for small mammals and found that camera trap surveys detected similar species and were more efficient and cost effective. Perkins-Taylor and Frey (2018) used camera traps for their occupancy analysis of *N. q. oscuraensis*. Although a single camera may have a lower detection probability than an extensive trap array, a camera can be left to run for multiple days, efficiently capturing multiple independent surveys without the presence of researchers. Finally, camera traps are non-invasive, with no potential for trap related mortality, which is ideal when working with a rare species in a high elevation location with frequent storms and changing weather. A pilot study conducted during 2018 found that cameras were suitable for use for an occupancy study of *N. m. atristriatus* (Frey and McKibben 2018).

B. Methods

i. Assumptions

A single season-single species occupancy model depends on four basic assumptions: closure, no false positives, no unexplained heterogeneity in detection, and no unexplained heterogeneity in occupancy (MacKenzie et al. 2018). Below, we discuss how our study design meets each of these assumptions.

Closure – the occupancy status of a unit does not change for the duration of the sampling season. We conducted our surveys June through September 2019. If juveniles were dispersing during our survey period, then occupancy probabilities should be interpreted as site use rather than strict occupancy (Mackenzie et al. 2018).

No false positives – there is no species misidentification resulting in false positives. Because we used camera trap photos for identification, the potential for false positives and false absences is a real concern. Gray-footed chipmunk (*Neotamias canipes*) and *N. m. atristriatus* have similar pelage and are difficult to discriminate. We have developed and tested characteristics that allow us to unambiguously identify these chipmunks based on photographs (Frey and McKibben 2018). We will only use records with high confidence of identification; this will lower detection probability, but will not bias our estimators (Kery and Schaub 2012).

No unexplained heterogeneity in detection – differences in detection between sites or between surveys must be modeled using covariates. Covariates for detection are described below.

No unexplained heterogeneity in occupancy – differences in occupancy between sites or between surveys must be modeled using covariates. Covariates for occupancy are described below.

Influence of covariates on detection probability and occupancy probability

Occupancy modeling will allow us to model detection probability (p) either as a constant across sites or as a function of site- and survey-specific covariates. We will also model occupancy (psi) as a function of micro- and macrohabitat covariates that we hypothesize to be influential for occupancy based on the limited literature about *N. m. atristriatus* ecology and on the preliminary data from our pilot study.

1. Influence of covariates on detection (see Table 1)

Bait aging – As bait ages, it may dry up and lose its attractiveness to chipmunks, resulting in a decrease in detection probability as a function of time passed since bait deployment. In a similar occupancy study of chipmunks using baited remote cameras, Perkins-Taylor and Frey (2018) tested bait aging as a covariate for detection probability but found no evidence that the strength of bait diminished over time. We hypothesized that there would be no decrease in detection probability as a function of bait age.

Learned response to bait – A chipmunk who has visited a bait station may be more likely to visit again or may learn that the food is inaccessible and not return on subsequent days. This would result in a change in detection probability for surveys following an initial detection. Perkins-Taylor and Frey (2018) found no evidence for a change in bait response following an initial detection. We hypothesized that detection probability would not change after an initial encounter with the bait.

Daily temperature – Because *N. m. atristriatus* is a high elevation, cold-adapted species, high maximum temperatures could decrease the time spent mating or foraging. We hypothesized that detection probability would be negatively related to daily maximum temperatures.

Predation risk – *Neotamias* species alter their vigilance and foraging behavior depending on perceived predation risk (Schmidt et al 2008). Least chipmunks are often found associated with thick herbaceous cover, so we hypothesized that, unlike other species of chipmunks, they depend on grasses, forbs, and shrubs to provide cover from predation (Carleton 1966, Sheppard 1971, Vaughn 1974, Meredith 1976, Bergstrom and Hoffman 1991, Bihr and Smith 1998, Root et al. 2001, Hadley and Wilson 2004, Nagorsen 2004, Poffenroth and Matson 2007, Rodhouse et al. 2010, Storm and Choate 2012). *N. m. atristriatus* is also commonly associated with boulders, stumps, and downed trees, which may provide cover and lookout posts for predator detection (Sheppard 1971, Vaughn 1974, Meredith 1976, Nagorsen 2004). We hypothesized that detection probabilities would be higher for bait tubes placed in areas with thick herbaceous and shrubby cover. We hypothesized that detection probabilities would be higher for bait tubes placed near boulders, stumps, and downed logs, which can provide escape cover and lookout posts.

Competition – Least chipmunks are known to be subordinate to other chipmunk species throughout their range (Sheppard 1971, Meredith 1976, Bergstrom 1986, Root 2001, Nagorsen 2004, Poffenroth and Matson 2007). Poffenroth and Matson (2007) found that *N. minimus* was frequently chased off by co-occurring yellow-pine chipmunk (*Neotamias amoenus*), and *N. minimus* was excluded from forest areas through social dominance and aggressive interactions. Sheppard (1971) also found that *N. m. oreocetes* was excluded from forest habitats by *N. amoenus*. Nagorsen (2004) found that *N. amoenus* was dominant to *N. m. oreocetes* in forested habitats. If the bait tube is placed in an area that directly increases the competition with *N. canipes*, we hypothesized that detection probability would decrease. *N. canipes* primarily feeds on the seeds of spruce, fir and pine cones, and is generally associated with conifer forests (Bailey 1931, Hope and Frey 2000). We expect that *N. m. atristriatus* may avoid areas with a higher concentration of *N. canipes* food. We hypothesized that detection would be negatively related to the number of mature trees and with the interaction between the number of mature trees and the date. If trees directly surrounding the bait tube are producing more food for *N. canipes, N. m. atristriatus* may be less likely to inspect the bait. We also hypothesized that detection would decrease in areas where *N. canipes* was caught more frequently on the camera traps and where there were more incidental observations of *N. canipes*.

Date – Chipmunks go into seasonal torpor during winter months (Yahner and Svendsen 1978, Nagorsen 2004). Nagorsen (2004) posits that subspecies and local populations of least chipmunks may be adapted to local environments and so time hibernation accordingly. There are currently no data on when *N. m. atristriatus* emerges from hibernation or begins hibernation again in the fall. We hypothesized that detection probability would be lower at the beginning and end of the summer, and highest in the middle.

2. Influence of covariates on occupancy (see Table 2)

Competition – As previously stated, least chipmunks are known to be subordinate to other co-occurring species of *Neotamias*. We hypothesized that an increase in forest density and an increase in food species for *N. canipes* would lead to a decrease in occupancy probability by *N. m. atristriatus*. We also hypothesized that distance to forest edge would be positively correlated to *N. m. atristriatus* occupancy (e.g., a site in a meadow near a forest edge may have a lower probability of occupancy than a site in a meadow far from a forest edge).

Predation – As described above, *Neotamias* species alter their vigilance and foraging behavior depending on perceived predation risk (Schmidt et al 2008). Least chipmunks are often found associated with thick herbaceous cover, so we hypothesized that unlike other species of chipmunks, they depend on grasses, forbs, and shrubs to provide cover from predation (Carleton 1966, Sheppard 1971, Vaughn 1974, Meredith 1976, Bergstrom and Hoffman 1991, Bihr and Smith 1998, Root et al. 2001, Hadley and Wilson 2004, Nagorsen 2004, Poffenroth and Matson 2007, Rodhouse et al. 2010, Storm and Choate 2012). *N. minimus* is also commonly associated with boulders, stumps, and downed trees, which may provide cover and lookout posts for predator detection (Sheppard 1971, Vaughn 1974, Meredith 1976, Nagorsen 2004). We hypothesized that occupancy would be positively correlated with shrub cover, herbaceous cover, rocky cover, and log cover and negatively correlated with bare ground. We also hypothesized that occupancy would be higher in areas with higher visual obstruction.

Food – Bergstrom (1986), Carleton (1966), and Vaughn (1974) all agree that the main food species for *N. minimus* include seeds and flowers from grasses, forbs, and shrubs. We hypothesized that occupancy would be positively correlated with cover of grass, forb, and shrub species, which might be used as food. We also hypothesized that sites within forest and other non-meadow habitat types would have higher occupancy when the distance to meadow edge is shorter because we expect that meadow species provide most of *N. m. atristriatus* food sources. We hypothesized that slope would be negatively correlated to occupancy because steeper slopes may hold less water and so support less productive vegetation and food sources (Davis and Goetz 1990). We hypothesized that heat load would be positively correlated to occupancy, because warmer temperatures may support more productive vegetation and food sources (Sternberg and Shoshany 2001).

Hibernation site – Chipmunks enter hibernation during the winter, and there is some evidence that the winter snowpack provides better insulation for hibernating animals (Svendsen 1974, Nagorsen 2004, Yandow et al. 2015). Yandow et al. (2015) used the number of days below -5°C as an indication of temperatures low enough to support an insulative snow pack and found it to be predictive of pika (*Ochotona princeps*) occupancy to a point, although past a threshold there were too many days of very cold weather for pikas to withstand. We hypothesized that sites with a stable insulating winter snowpack would have higher occupancy probability, as measured by days below -5°C. Contrary to our food hypothesis, we hypothesized that heat load could be negatively correlated to occupancy, because sites with a lower heat load support snow pack later into the spring.

Den site – Bihr and Smith (1998) found that least chipmunks preferentially chose den sites under larger available rocks. Vaughn (1974) found that they were associated with stumps and rocks that served as lookouts and logs as routes of escape. We hypothesized that den sites would be associated with larger rocks, stumps, and logs, and so occupancy probability would be higher at sites with more rocks, stumps, and logs.

Habitat type – In the literature, least chipmunks are most commonly associated with alpine meadows, talus, and alpine tundra (Carleton 1966, Sheppard 1971, Vaughn 1974, Meredith 1977, Bergstrom and Hoffman 1991, Bihr and Smith 1998, Hadley and Wilson 2004, Nagorsen 2004). They are also occasionally associated with disturbed forests (Hadley and Wilson 2004, Storm and Choate 2012, Peterson et al. 2017). They have been found to be less abundant or not present in conifer forest (Sheppard 1971, Meredith 1977, Chappell 1978, Bergstrom and Hoffman 1991, Nagorsen 2004, Rodhouse et al. 2010, Peterson et al. 2017). However, in our preliminary analysis from the pilot study, we found that the species was not associated with talus or burnt forest but that it was closely associated with shrub habitat (McKibben and Frey unpublished data). We hypothesized that occupancy probability would be higher in shrub-dominated habitats, including meadow with shrubs, sparse conifer forest and sparse burnt forest with a dense shrub matrix.

Elevation – Elevation is often a proxy for habitat type that can be used as a predictor of species occupancy. Generally, similar elevations support similar species and habitats; however, a higher elevation site may support lower elevation species depending on other abiotic factors such as temperature, aspect, heat load, precipitation, etc. Still, all historical records of *N. m. atristriatus* in the White Mountains are at least 3100 m (10,200 ft) in elevation (Frey 2016). We hypothesized that occupancy would generally be higher at higher elevations.

ii. Data Collection

Study area – Surveys occurred from 2 June to 7 October 2019 in the Sierra Blanca subrange of Lincoln National Forest. The study site was above 2500 m (8,200 ft) and was bounded on the south by the Mescalero-Apache reservation (Figure 1). The majority of the study site was within the White Mountains Wilderness Area.

Site selection – We focused our surveys on major land cover types present in the White Mountains that provide potential least chipmunk habitat. Preliminary analysis of habitat associations based on our 2018 pilot study suggested that *N. m. atristriatus* is associated with shrubs and sparse forest. We excluded areas of non-habitat, including open monotypic grasslands, dense conifer forest, and dense burnt forest.

Because available land cover data for the study area have very low spatial resolution and are not applicable to the life history of a chipmunk, we created a high resolution land cover map for the Sierra Blanca subrange above 2500 m (8200 ft) in elevation. We obtained USGS National Agriculture Imagery Program (NAIP) data, which are 4-band imagery with 1 m spatial resolution, for the study area with images from 25 May 2016. Using the ArcGIS Pro Image Classification toolset, we performed an unsupervised, segmented classification of the study area. We manually assigned classes using sites with known land cover and by comparing to available imagery (Google Earth and ESRI basemap). Known land cover classes were based on the author's personal experience and on georeferenced photographs (Google Maps Streetview). The final classified map had 1 m spatial resolution and included six classes: conifer forest, deciduous forest, dead forest, grass/herbaceous, shrub, and dirt/rock.

Chipmunks select for a specific configuration of biotic and abiotic factors across the landscape, so it was necessary to define *a priori* biologically relevant land cover types based on the percent cover and area of contiguous cover of the original six classes. We used Raster Calculator, Focal Statistics, and Region Group tools in ArcGIS Pro to define eight land cover types, based on the percent cover of the six classes within a 30x30 meter moving window (Table 3; Figure 2). We manually digitized edges, defined as areas where conifer forest abutted directly on meadows and grasslands, while searching at a 1:2000 scale. We then added an 80 m buffer around edges, extending into the forest and grasslands.

We stratified survey sites evenly between high (>2800 m) and low (2500-2800 m) elevation, to ensure that low elevation areas were not over-sampled. We placed sites in a random stratified design within each elevation stratum, so that we surveyed each land cover type in proportion to its distribution across each elevation stratum. We placed sites within 40-200m of roads or of easily accessible backcountry trails to facilitate access and we required a minimum distance of 160 m between survey sites. Using telemetry and tracking data from least chipmunks in Colorado and Montana, we have estimated an average home range size of 2 ha for adult least chipmunks, and 160 m is approximately the diameter of a 2 ha circle (Bergstrom 1988; Martinsen 1968). Our preliminary results indicate that this is an overestimate for the subspecies at our study area (See Home Range Results, Table 15). Following these spacing rules, we identified 300 survey sites, half accessible by road and half accessible only by backcountry trails (Figure 3).

Number of surveys – Using presence/absence data collected during a pilot study conducted June – August 2018 at 39 sites in potential *N. m. atristriatus* habitat, we estimated detection probabilities for the subspecies, while holding occupancy probability constant, in the unmarked and MuMin packages in R. As potential detection covariates, we considered our field collected, site-specific habitat data and daily precipitation/temperature data, obtained from the NOAA National Centers for Environmental Information for the Sierra Blanca Trail weather station. Data exploration revealed that the sample size was too small to robustly estimate variation in detection as a function of our field collected habitat covariates.

Based on significance in univariate detection models and correlation with other variables, we settled on maximum daily temperature and the presence/absence of precipitation as the final pair of detection covariates. We tested all combinations of the two detection covariates as well as the naïve model. We assessed model fit using Akaike's Information Criterion for small sample size (AIC_c) and considered models with $\Delta AIC_c < 2$ as competitive models. There were two competitive models, and the top detection model included both maximum daily temperature and precipitation, while the next best model included only maximum daily temperature (Table 4).

We used the top model to predict detection probabilities under a range of weather scenarios based on the temperature and precipitation history in 2018 that we obtained from the NOAA National Centers for Environmental Information for the Sierra Blanca Trail weather station. We found that 3 survey days would be sufficient to achieve a 90% likelihood of at least one detection under 81% of the weather conditions seen in 2018 (Table 5). Consequently, all cameras were deployed for at least 3 days. While in the field, we monitored daily weather conditions and, during long dry spells with warm temperatures (no precipitation and maximum temperatures > 67°F), we extended survey periods to 5-6 days.

Camera deployment – At each location, a remote camera (Reconyx PC800 HyperFire) was mounted vertically approximately 45 cm above the ground using a PVC frame and tent stake. The camera trap was baited with peanut butter placed inside a PVC tube with holes to allow scent to escape. The bait tube was positioned roughly 1 m from the camera.

Photograph identification – Using the Colorado Parks and Wildlife (CPW) Photo Warehouse Microsoft Access application, two independent observers screened all photographs and tagged all photographs containing images of chipmunks (Newkirk 2016). Because *N. m. atristriatus* co-occurs with the morphologically similar *N. canipes,* photographs of chipmunks must be identified by trained observers using our chipmunk identification key (Frey and McKibben 2018). Each chipmunk photograph was identified to species by two independent, trained lab assistants (Supplemental Materials: Chipmunk Identification Training). In addition, the trained lab assistants reported a numeric confidence rank from 1 to 4 for each photograph. These ranks reflected how confident they were in assigning the species identification, from very confident (4), somewhat confident (3), not very confident (2), to no confidence (1). Photographs identified as *N. canipes* with a confidence rank of 4 by both observers were considered to be confirmed *N. canipes* detections. All other photographs were reviewed and assigned a confidence rank by an expert (Frey or McKibben).

Core sampling areas – In late July 2019, we became concerned that our original sampling plan would not yield enough detections to perform analysis; by this time there were only about 5 detections of *N. m. atristriatus* from 124 sites surveyed. Consequently, we reevaluated and adjusted our original sampling plan to ensure a sufficient number of sites with detections. To do this, we designated a set of core sampling areas. These core areas represented three of the highest elevation peaks in the study area, two of which contained confirmed sub-populations. The core areas were Lookout Mountain, Nogal Peak, and Monjeau Peak. We did not include Buck Mountain as a core area because recent surveys failed to verify presence of the species. We distributed an additional set of random points within each of the core areas and sampled a subset of these locations, depending on logistics.

The Lookout Mountain core sampling area was defined using the lowest elevation *N. m. atristriatus* detection in the area. This detection location was buffered by 80 m to approximate the lowest boundary of an *N. m. atristriatus* home range. Using telemetry and tracking data from least chipmunks in Colorado and Montana, we have estimated an average home range radius of 80 m (Martinsen 1968, Bergstrom 1988). Our preliminary results indicate that this is an overestimate for the subspecies at our study area (See Home Range Results, Table 15). Using the 80 m buffer, the lower limit of the Lookout Mountain core sampling area was at 3248m. The Lookout Mountain core sampling area was further delineated within 200 m of backcountry trails or anywhere within the slopes of Ski Apache ski area that fell above the elevation limit. The Nogal Peak core sampling area was defined above 2750 m, which is the elevation at which Trail 25 circumnavigates the mountain. The area was further bounded along the Skull Springs Trail on the southwest and the Nogal Canyon Trail on the northeast. The species was detected within this sampling area during pilot study surveys in 2018. The Monjeau Peak core sampling area was also delineated above 2750 m and was bounded along the Rodamaker Canyon and Telephone Canyon trails. Within the Nogal Peak and Monjeau Peak core sampling areas, trail buffers were not applied.

To accommodate the increased number of survey sites within the core areas, we reduced the minimum distance between survey sites to 80 m, the mean radius of a least chipmunk's home range. We assigned 94 random points within the Lookout Mountain core area, 99 random points within the Nogal Peak core area, and 81 random points within the Monjeau Peak core area (Figure 3). We sampled a subset of these locations, depending on logistics (i.e., accessibility and time constraints due to other aspects of the project occurring simultaneously). At Lookout Mountain, we did not survey sites that fell within or near heavy construction due to ski area maintenance or sites that fell within dense burned forest.

Microhabitat data collection – At each survey site, we collected ground cover and plant composition data on three equally spaced 20 m transects radiating from the survey site. Microhabitat data collection occurred either simultaneously with or after the camera trapping period. Transect direction was selected at random. Every tree >10 cm diameter at breast height (DBH) within one meter of each transect was counted, identified to species, and assigned to a 10 cm size class. Within one meter of each transect, we counted every boulder >0.5 m width, every stump (defined as a dead tree still rooted <1 m high), and every log >10 cm diameter.

Using a cover pole design modified from Griffith and Youtie (1988), we measured visual obstruction at the site center and every 10 m along each transect. The cover pole was a 1 m pole with 10 cm strips in alternating colors. A strip was considered covered if at least 25% was obstructed from view. We read the cover pole at 1 m eye level from a distance of 5 m. The cover pole was read from the transect, so the center readings and 10 m readings were taken facing towards the site center, while the 20 m readings were taken facing away from the site center. We estimated ground cover using the Daubenmire method, which is a method for estimating ground coverage by species or by class (Daubenmire 1959). We estimated ground cover classes at 1 m from the camera site and then every 2 m along the remainder of each transect using a 20x50 cm quadrat and classing categories as defined by Daubenmire (1959; 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, >95%). Daubenmire readings were taken from 1 m height above the ground. Ground cover classes and their hypothesized function with respect to *N. m. atristriatus* are listed in Table 6.

We measured canopy cover using a spherical densiometer in four directions from the camera trap site. From the survey site center, we recorded distance to and species of the nearest tree >10 cm DBH and of the nearest shrub. Within a 10 m radius of the camera site, we recorded the height and species of the tallest shrub, the height of the tallest boulder, and the height of the tallest log. We measured site center attributes within a 10 m radius of the camera because we hypothesized that detection might be higher at site with flee cover available within this radius. Clarke (1993) found that *Neotamias* will flee approximately 10 m (5.4 ± 0.3 m when near their burrows and 11.4 ± 0.7m when outside their home range). We deployed DS1923 Hygrochron iButtons (Thermodata, Whitewater, WI, USA) to record temperature at every camera trap site.

Macrohabitat data collection – Using a 10 m spatial resolution digital elevation model (DEM) available through the USDA NRCS GeoSpatial Data Gateway, we created relevant topographic variables at three scales (20 m, 40 m, and 80 m radius moving windows). Using the Vector Ruggedness Measure (Terrain Ruggedness) Toolbox for ArcGIS10.x and the DEM, we calculated terrain ruggedness, which is an index of the variation in three-dimensional orientation of grid cells within a neighborhood (Sappington et al 2007). We calculated heat load index, which is an estimate of the potential annual direct incident radiation, depending on latitude, slope, and aspect, using the DEM and the Heat Load Index tool from the Geomorphometry and Gradient Metrics Toolbox (McCune and Keon). We calculated the topographic position index using the Topography Toolbox to compare elevation of each cell to the mean elevation of the neighboring cells. Hillshade represents the relative amount of local light, based on the topography and the position of the sun in the sky, and was calculated using the Hillshade Tool. Hillshade was averaged across 9am, 12pm, and 3pm for all 2019 solstices and equinoxes. We calculated mean summer NDVI across May to September, 2019 using red and infrared band data from Landsat 8 Level-2, obtained through the USGS Earth Explorer.

To inform an improved land cover classification, we collected ground-truth data points throughout the study area. At each ground-truth data point, we identified and marked the dominant land cover class using a portable GPS unit. We collected dominant land cover class in areas where a single species was dominant within a 3 m radius (i.e., in the middle of a gooseberry shrub or directly at the base of a tree). Cover classes included tall grass (taller than 20 cm), short grass (shorter than 20cm), lupine (*Lupinus* sp.), mountain iris (*Iris missouriensis)*, fern, unknown forb, dirt, bedrock, talus, gooseberry (*Ribes sp.*), gooseberry currant (*Ribes montigenum)*, orange gooseberry (*Ribes pinetorum*), snowberry (*Symphoricarpos sp.*)*,* New Mexico locust (*Robinia neomexicana*) tree (taller than 2 m), *R. neomexicana* shrub (shorter than 2 m), Gambel's oak (*Quercus gambelii*) tree (taller than 2 m), *Q. gambelii* shrub (shorter than 2 m), unknown shrub, quaking aspen (*Populus tremuloides)*, unknown deciduous tree, Engelmann's spruce *(Picea engelmannii),* Douglas fir (*Psuedotsuga menziesii*), white fir (*Abies concolor*)*,* subalpine fir (*Abies lasiocarpa*)*,* limber pine (*Pinus flexilis*)*,* ponderosa pine (*Pinus ponderosa*)*,* pinyon pine (*Pinus edulis*)*,* juniper (*Juniperus sp.*)*,* unknown conifer tree, and dead conifer tree.

We have not yet completed an improved land cover classification for the occupancy study area. Using the ArcGIS Pro Image Classification toolset we will use these ground-truth data to perform a supervised segmented classification of the study area. This map will be used to determine vegetation type as well as distance to forest patch, distance to live forest edge, distance to burnt forest edge, distance to meadow, distance to talus/rock patch, and distance to water.

Analysis methods – We will run a single season occupancy model in programs R and JAGS using the jagsUI and R2jags packages. We will use our list of conceptual, *a priori* models to create a set of statistical models for analysis. We will assess model fit using the Deviance Information Criterion (DIC), which is a generalization of the Akaike Information Criterion that is suited to Bayesian model selection.

C. Results

We deployed camera traps at a total of 239 locations. Cameras were deployed between 2 June and 7 October 2019 for a total of 1,220 camera trap days and 377,419 photographs. We deployed 124 of the cameras as part of the original stratified sampling scheme and an additional 115 cameras in the core sampling areas (Figure 2; Figure 3).

At each camera site, we collected ground cover, plant composition, canopy cover, visual obstruction, and temperature data. Data entry is in progress, and we anticipate completing habitat data entry by early February 2020.

Using the CPW Photo Warehouse, two independent observers have reviewed all 377,419 photographs and tagged all photographs containing images of chipmunks. Chipmunks of any species have been detected in 13,964 photographs at a total of 100 sites (see Supplemental Materials: Camera Deployment). Each of the 13,964 chipmunk photographs was identified to species by two independent trained lab assistants and was assigned a confidence.

We collected approximately 2000 ground-truth data points throughout the study area. We anticipate completing the supervised segmented classification of the study area and evaluation of detection and occupancy macrohabitat covariates by early April 2020.

We anticipate completing the model selection process for the single season occupancy models by late April 2020.

Table 1. *Survey and site specific variables and hypothesized effect on detection probability*

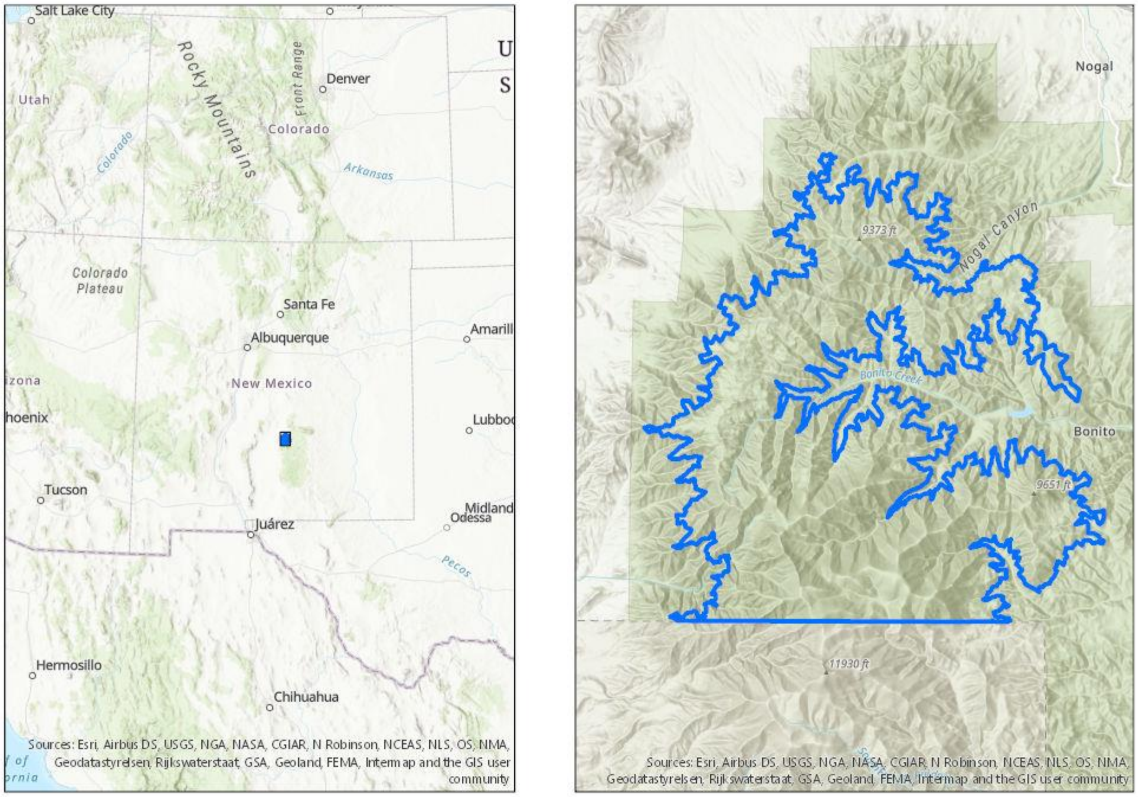
Category	**Covariate**	**Function (relative to increase in covariate)**	**Effect**	**Measurement**
bait aging	days since deployment	less attractive as time passes	none	days since deployment
learned response to bait	first or subsequent visit to bait	may avoid bait tube after learning that bait is inaccessible	none	before/after first detection
climate	temperature	will forage more in warmer temperature	(+)	iButton data
	rain	will forage less during rains	(-)	weather station – hours of rain per day
	date	may be in hibernation	(+)	date
predation risk	distance to tree	increasing distance from a tree increases the distance to habitat for aerial predators	(+)	distance to nearest tree with a DBH > 10 cm
	shrub cover near camera	increasing escape cover	(+)	% shrub cover - Daubenmire frame and cover pole every 2 m for first 10 m of transects
	herbaceous cover	increasing escape cover	(+)	% herbaceous cover - Daubenmire frame and cover pole every 2 m for first 10 m of 3 transects
	boulder cover near camera	increasing escape cover	(+)	% rock at camera site - Daubenmire frame and cover pole every 2 m for first 10 m of 3 transects
	bare ground near camera	increasing exposure	(-)	% bare ground at camera site - Daubenmire frame and cover pole every 2 for first 10 m of 3 transects
	distance to nearest shrub	closer escape cover	(-)	distance to nearest shrub - if distance is greater than 10 m, don't count (*Neotamias* have shown a fleeing distance of approximately 10 m)
	distance to nearest boulder	closer escape cover and lookout	(-)	distance to nearest boulder >0.5 m diameter - if distance is greater than 10 m, don't count
	look out posts (stump, rock, etc.)	provide lookout for predators	(-)	distance to nearest stump (dead tree still rooted, less than 1 m high) - if distance is greater than 10 m, don't count
	logs/fallen branches	avenues of escape and lookouts	(-)	distance to nearest log or branch > 10 cm diameter - if distance is greater than 10 m, don't count
competition	trees	better for N. *canipes*, so *N. m. atristriatus* will not compete for the bait station	(-)	number of trees in microhabitat (trees with DBH >10 cm within 1 m of transects)
	forest patch	distance to forest patch	(+)	GIS/satellite imagery - forest patch defined as 5 or more trees
	presence of *N. canipes*	will not compete with *N. canipes* for the bait station	(-)	camera trap data; incidental observations
	number of trees * date	more mast production by trees, there will be more *N. canipes* foraging in this microhabitat	(-)	number of coniferous trees within belt transects

Table 2. Environmental variables and hypothesized effect on occupancy probability

Category	**Covariate**	**Function (relative to increase in covariate)**	**Effect**	**Measurement**
competition	presence of *N. canipes*	exclusion and competition	(-)	camera trap data and incidental observations
	forest density	increased presence of *N. canipes*, leads to decreased occupancy by *N. m. atristriatus*	(-)	canopy cover - in four directions from camera trap site
	pine cones/acorns	increased presence of *N. canipes*	(-)	% cover pine cones/acorns on ground - Daubenmire frame every 2m along 3 20m transects
	tree species	food species for *N. canipes* will decrease *N. m. atristriatus* occupancy	(-)	count, species, and 10 cm size class of every tree greater than 10 cm DBH within 1 m of 3 20m transects
	distance to *N. canipes* habitat	further from forest, there will be more *N. m. atristriatus*	(+)	GIS - distance to live forest edge
predation	shrub cover - density	provide cover from predators	(+)	% cover - Daubenmire frame every 2 m along 3 20 m transects
	herbaceous cover - density	provide cover from predators	(+)	% cover - Daubenmire frame every 2 m along 3 20 m transects
	rocky cover	provide cover from predators	(+)	% cover - Daubenmire frame every 2 m along 3 20 m transects
	log cover	provide cover from predators and escape routes	(+)	% cover - Daubenmire frame every 2 m along 3 20 m transects
	bare ground	less cover from predators or escape routes from predators	(-)	% cover - Daubenmire frame every 2 m along 3 20 m transects
	visual obstruction	provided by shrubs, herbaceous layer, logs, etc	(+)	cover pole every 10 m along 3 20 m transects
food	grass cover - seed production	food source	(+)	% cover by species - Daubenmire frame every 2 m along 3 20m transects
	forb cover - seed production	food source	(+)	% cover by species - Daubenmire frame every 2 m along 3 20m transects
	shrub cover - seed production	food source	(+)	% cover by species - Daubenmire frame every 2 m along 3 20m transects
	distance to meadow edge	further from meadows edge is further from food source (e.g., in a talus field, I predict that likelihood of occupancy is greater nearer to a meadow's edge)	(-)	Distance to meadow's edge, determined using classified land cover class map

	slope	steeper slope will hold less water and so support less productive herbaceous and shrub cover	(-)	Calculated from DEM using Slope Tool in Spatial Analyst Tools ArcGIS Pro
	heat load	with warmer temperatures, shrubs, grasses, and forbs will be more productive	(-)	McCune and Keon Heat Load Index, calculated from DEM based on latitude, slope, and aspect
	hillshade	Relative amount of illumination based on topography, latitude, and sun's position	(+)	Calculated from DEM using Hillshade tool in ArcGIS Pro. Averaged across 9am, 12pm, and 3pm for 2019 solstices and equinoxes
	water source	nearer to water, shrubs, grasses, and forbs will be more productive	(-)	Distance to water, calculated from Lincoln National Forest streams database
hibernation	winter snowpack	better hibernation habitat with more snowpack	(+)	Number of days below -5°C (indicates where temperatures are low/snowpack is more insulating)
den	rock cover	cover for burrow	(+)	every boulder > 0.5 m width within 1 m of transects
	prominent perch	lookout for predators	(+)	every stump (dead tree still rooted, less than 1 m high) within 1 m of transects
	log cover	cover for burrow	(+)	every log > 10 cm diameter within 1 m of transects
	talus	cover for burrow	(+)	Cover class map.
habitat type	conifer forest		(-)	Cover class map.
	aspen forest		(+)	Cover class map.
	burnt forest		(+)	Cover class map.
	disturbed (ski run)		(+)	Cover class map.
	meadow		(+)	Cover class map.
	alpine tundra		(+)	Cover class map.
elevation			(+)	Digital Elevation Model 10 m spatial resolution, downloaded from the USDA GeoSpatial Data Gateway.

Figure 1. Map of study area, bounded by 2500m and the Mescalero Apache Reservation.



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community

Table 3. Definitions of land cover classes used to create a land cover map for the study area. Defined based on a 30 x 30 m moving window.

Land cover Class	**Description**
Deciduous	Greater than 30% deciduous tree
Shrub dominant	Greater than 15% shrub and less than 20% conifer (dead or alive); excluded contiguous conifer
Contiguous conifer	Area of contiguous conifer (dead or alive) greater than 2 ha (1 *N. minimus* home range), holes less than 2 ha defined as majority surrounding
Sparse live conifer	Non-contiguous forest, greater than 10% live conifer
Sparse dead conifer	Non-contiguous forest, greater than 10% dead conifer
Contiguous grassland	Area of contiguous herbaceous cover greater than 2 ha (1 home range), holes less than 2 ha defined as majority surrounding
Edge	Area of overlap between 80m buffers (radius of *N. minimus* home range) at the boundary between grassland and forest habitat and contiguous conifer forest and contiguous grassland
Other	Area that does not fall into any other class, mainly composed of rock and dirt, but includes areas that are <15% shrub, <10% conifer and <30% deciduous

Figure 2. Land cover map of the study site, created using the Image Classification toolset in ArcGIS pro. Right-hand image shows the Lookout Mountain-Ice Springs study area.

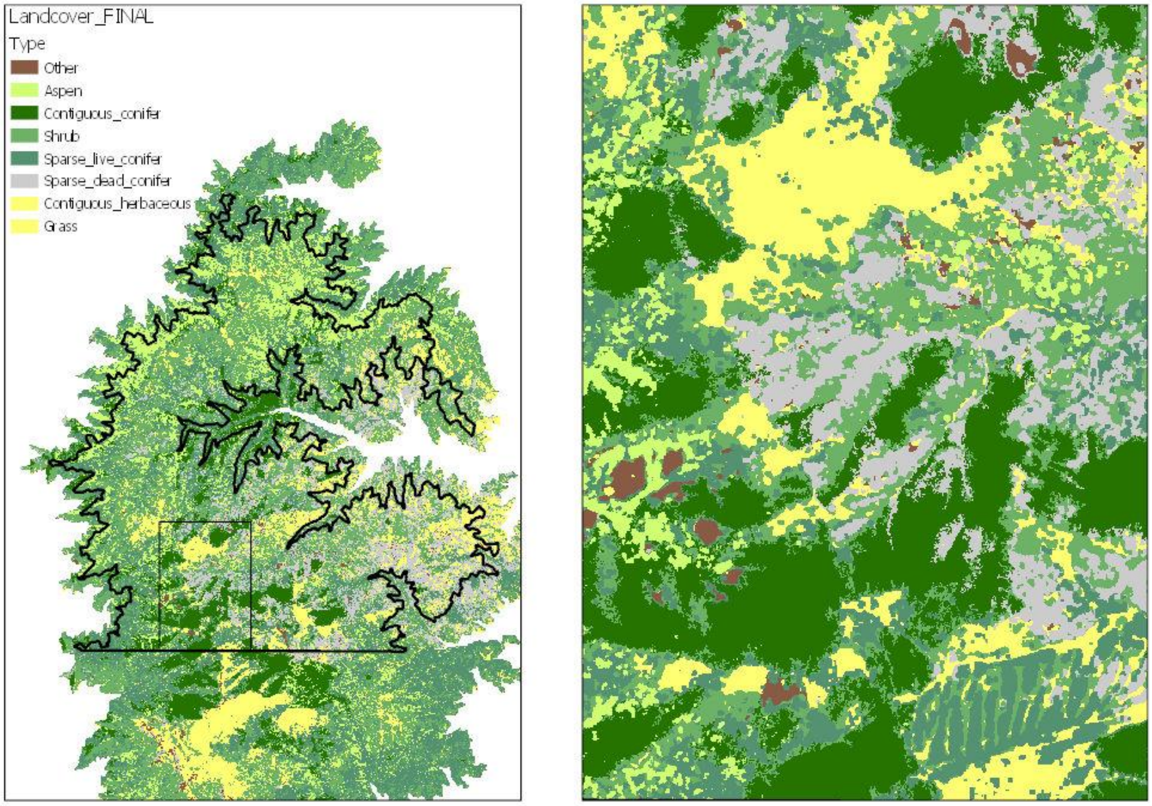


Figure 3. Camera survey locations, stratified by land cover type and elevation, placed within 200 m buffers along roads and trails. Roads are shown in blue; trails are shown in green; camera locations are shown in red.

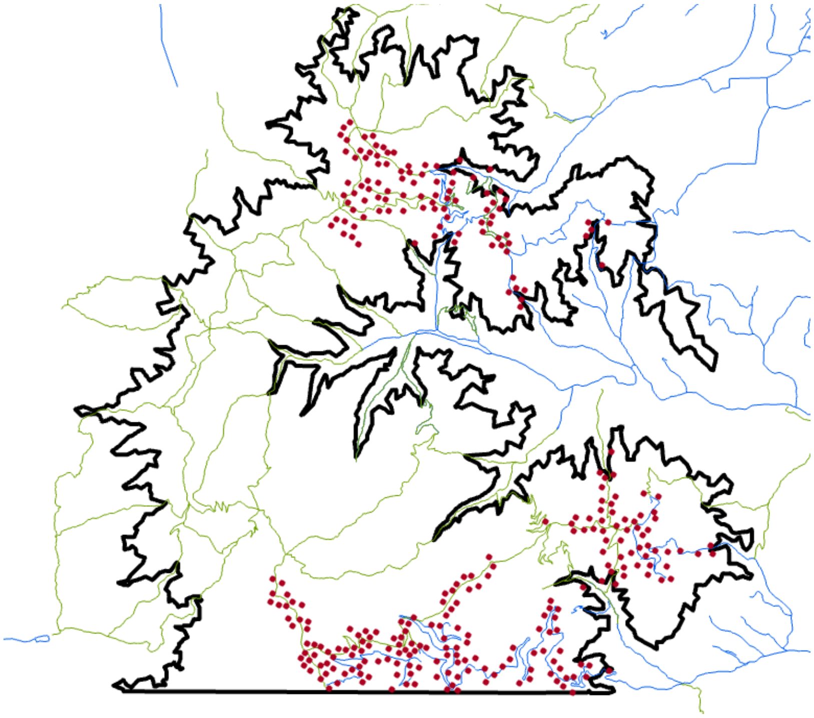


Table 4. Model selection table for detection covariates that were fit to data collected during 2018 pilot study. Used as predictive model to inform survey length.

Model names	Intercept	Precipitation	Maximum temperature	K	AICc	ΔAICc	AICc wt
precipitation + max temp	-1.70	1.11	-0.19	4	92.70	0.00	0.48
max temp	-1.70		-0.20	3	92.80	0.10	0.46
precipitation	-1.70	1.08		3	97.70	5.00	0.04
null model	-1.70			2	98.40	5.70	0.03

*Positive parameter estimate for precipitation indicates a higher probability of detection on days with precipitation. Negative parameter estimate for temperature indicates a lower probability of detection on days with higher temperatures.

Table 5. Table for calculating the number of surveys days necessary for reaching a 90% likelihood of at least one detection, depending on the weather conditions.

		Daily maximum temperature in degrees F				
		≤58°	**58°-62°**	**63°-67°**	**67°-72°**	**≥72°**
Precipitation	% of days that met these weather conditions	15%	8%	12%	4%	0.60%
	Probability of detection	p=0.93	p=0.90	p=0.77	p=0.56	p=0.47
	Days necessary to achieve 90% likelihood of at least one detection	1	1	2	3	4
No precipitation	% of days that met these weather conditions	12%	12%	18%	12%	6%
	Probability of detection	p=0.81	p=0.74	p=0.53	p=0.3	p=0.23
	Days necessary to achieve 90% likelihood of at least one detection	2	2	3	7	9

** Percentages represent the percent of days from 15 May - 30 October 2018 that met those weather conditions

Table 6. Daubenmire classes collected during microhabitat data collection and their hypothesized function with respect to Peñasco least chipmunk (Neotamias minimus atristriatus).

Daubenmire Classes	**Hypothesized function**
Holodiscus dumosus	predation avoidance/food
Quercus gambelii	predation avoidance/food
Symphoricarpos rotundifolius	predation avoidance/food
Robinia neomexicana	predation avoidance/food
Ribes montigenum	predation avoidance/food
Ribes pinetorum	predation avoidance/food
Ribes wolfii	predation avoidance/food
Ribes cereum	predation avoidance/food
Fallugia paradoxa	predation avoidance/food
Lupinus sp.	predation avoidance/food
Achillea millefolium	
Iris missouriensis	
Artemisia sp.	
Grass	predation avoidance/food
Other shrub	predation avoidance/food
Other forb	predation avoidance/food
Picea engelmannii	competition/food
Picea pungens	competition/food
Pseudotsuga menziesii	competition/food
Abies concolor	competition/food
Abies lasiocarpa	competition/food
Pinus ponderosa	competition/food
Pinus flexilis	competition/food
Pinus edulis	competition/food
Populus tremuloides	
Dead tree	
Log (>10cm)	predation avoidance/den site
Bare ground/ small rock	predation/escape routes
Acorn/pinecone	competition/food

IV. Telemetry study

A. Introduction

While an occupancy analysis allows us to evaluate habitat selection on the landscape scale, species can select different habitat factors at different spatial scales. We used radio telemetry to gain fine scale information on macro- and microhabitat selection by *N. m. atristriatus*, as well as elucidating key natural history characteristics. These include movement patterns, home range, den site selection, and feeding behavior (Wright and Frey 2015). Johnson's second order of selection is defined as the selection of the location of a home range (Johnson 1980), which we will hereafter refer to as macrohabitat selection. In this case, we compared used locations from within a home range to available locations drawn from an area greater than the composite of all the home ranges. Johnson's third order of selection is defined as selection within a home range (Johnson 1980), or microhabitat selection, comparing used locations within a home range to available locations drawn from within the same home range. We used logistic regression with a use-availability design to estimate resource selection functions (RSFs) on both the macro- and microhabitat scales.

Surveys in 2016 confirmed *N. m. atristriatus* in two nearby areas at Lookout Mountain and Ice Springs (Frey and Hays 2017). Lookout Mountain is a sub-peak (3531 m; 11,584 ft) of Sierra Blanca, located within a large patch of subalpine meadow and tundra contiguous with that on Sierra Blanca Peak, and is characterized by rocky soil, sparse grass, alpine forbs, patchy gooseberry (*Ribes sp.*), and sparse Engelmann's spruce (*Picea engelmannii*). Ice Springs is a lower wetter meadow site (3424 m; 11,233 ft), characterized by large old growth *P. engelmannii*, dense and abundant gooseberry, and grassy meadow patches. We collared and tracked individuals in both areas using radio telemetry to identify home range boundaries and use, and we examined differences in selection patterns between the two areas.

To date, the best estimate of home range for least chipmunks is from Bergstrom (1988), who used radio telemetry relocation data from four least chipmunks in the Roosevelt National Forest of Colorado to estimate Minimum Convex Polygons (MCPs). MCPs are a common home range estimator, which draws the smallest possible polygon around the points of use. MCPs often overestimate home range because they can include unused areas within the home range polygon. We use MCPs to estimate home range so that our estimates are directly comparable to estimates available for least chipmunks in the literature. Additionally, Seaman et al (1999) suggests a minimum of 30 unique locations for estimates using Kernel density methods and we do not have sufficient sample sizes.

Macrohabitat scale analyses help define and explain the distribution of a species and the broad habitat characteristics necessary for a species. These analyses can direct managers towards identifying potential habitat and possible areas for reintroduction or restoration. Microhabitat scale analyses can identify biotic and abiotic factors that are key for the species persistence and/or recovery within patches of habitat that are known to be occupied. This information can help managers direct resources and effort effectively to preserve existing populations. Based on our limited understanding of the ecology of *N. m. atristriatus*, we considered four main categories of hypotheses to explain macro- and microhabitat selection: competition, predation, food choice, and habitat type.

Hypothesized influence of covariates on macro- and microhabitat selection

Competition – Least chipmunks are known to be subordinate to other chipmunk species throughout their range (Sheppard 1971, Meredith 1976, Bergstrom 1988, Root et al. 2001, Nagorsen 2004, Poffenroth and Matson 2007). Poffenroth and Matson (2007) found that *N. minimus* was frequently chased off by co-occuring *Neotamias amoenus,* and *N. minimus* was excluded from forest areas through social dominance and aggressive interactions. Sheppard (1971) also found that *N. m. oreocetes* was excluded from forest habitats by *N. amoenus*. Nagorsen (2004) found that *N. amoenus* was dominant to *N. m. oreocetes* in forested habitats. *N. canipes* primarily feed on the seeds of spruce, fir, and pine cones and are generally associated with conifer forests (Bailey 1931; Hope and Frey 2000). We hypothesized that, at both scales, *N. m. atristriatus* would avoid areas with increased potential for competition with *N. canipes*. We hypothesized that use would be negatively related to the density of conifer trees, and to other indicators of conifer forest, such as pine cones, logs, woody litter, and canopy cover.

Predation – *Neotamias* species alter their vigilance and foraging behavior depending on perceived predation risk (Schmidt et al 2008). Least chipmunks are often found associated with thick herbaceous cover, so we hypothesized that, unlike other species of chipmunks, they depend on grasses, forbs, and shrubs to provide cover from predation (Carleton 1966, Sheppard 1971, Vaughn 1974, Meredith 1976, Bergstrom and Hoffman 1991, Bihr and Smith 1998, Root et al. 2001, Hadley and Wilson 2004, Nagorsen 2004, Poffenroth and Matson 2007, Rodhouse et al. 2010, Storm and Choate 2012). *N. minimus* is also commonly associated with boulders, stumps, and downed trees, which may provide cover and lookout posts for predator detection (Sheppard 1971, Vaughn 1974, Meredith 1976, Nagorsen 2004). We hypothesized that, within their home ranges, *N. m. atristriatus* would use patches with increased shrub cover, herbaceous cover, rocky cover, and log cover. We also hypothesized that use would be higher in areas with greater visual obstruction. We hypothesized that, at the macrohabitat scale, use would be higher in areas with a greater proportion of shrub cover and in areas nearer to shrubs.

Food – Bergstrom (1988), Carleton (1966), and Vaughn (1974) all agree that the main food sources for *N. minimus* include seeds and flowers from grasses, forbs, and shrubs. We hypothesized that, at both spatial scales, *N. m. atristriatus* would use patches with cover from grass, forb, and shrub species. We also hypothesized that they would use patches with a greater diversity of food items available.

Habitat type - In our preliminary analysis from the pilot study, we found that the species was closely associated with shrub habitat (McKibben and Frey unpublished data). We also observed that the species was associated with sparse conifer forest, especially in the Lookout Mountain and Ice Springs area (McKibben and Frey, personal observation). We hypothesized that, at the macrohabitat scale, *N. m. atristriatus* would use shrub-dominated habitats, including meadow with shrubs and sparse conifer forest with a dense shrub matrix. We hypothesized that *N. m. atristriatus* would not use dense conifer forest or dense burned forest.

B. Methods

i. Animal collaring and tracking

Trapping effort – We used Sherman live trapping to capture individual *N. m. atristriatus* for collaring. During this trapping effort, Sherman traps were set in informal lines of roughly 40 traps spaced approximately 5 m apart, targeting known *N. m. atristriatus* locations and similar habitats. These surveys included 1000 trap days at Ice Springs from 29 May – 1 June, 500 trap days at Monjeau Peak from 3-4 June, 1920 trap days at the Nogal Peak trailhead from 14-19 June, and 300 trap days at Lookout Peak on 13 July (Table 7). At the end of the season, we trapped to remove collars, with 1500 trap days at Lookout Mountain from 8-12 September and 800 trap days at Ice Springs from 23-26 September. We did not trap at Monjeau Peak or Nogal Peak at the end of the season because no animals were collared at these sites.

Handling and collaring – Field methods followed those recommended by the American Society of Mammalogists (Sikes 2016) and as approved by the New Mexico State University Institutional Animal Care and Use Committee. Sherman live traps were checked as frequently as possible during the day and, to the extent practicable, were closed prior to severe weather events to prevent animal capture and exposure to extreme conditions. To reduce the possibility of hypothermia in trapped animals, we put bedding material in traps when weather conditions warranted and provided shelter over the traps to limit rain and sun exposure.

Upon capture, we transferred chipmunks to a zippered, mesh handling bag for processing and radio collar attachment. To minimize stress, we aimed to keep total handling time of captured individuals to less than 5 minutes. During handling, we evaluated the animal's stress (i.e., bulging eyes, rapid breathing, visibly agitated). We placed individuals that appeared unduly stressed back in the Sherman trap in a quiet, cool area and allowed the animal time to relax before we attempted to handle the animal again. If stress during the handling procedure was not adequately mitigated by removing the animal to a quiet spot to rest, we did not collect any further data and released the animal. We identified captured animals and collected data on external body measurements (e.g., tail length, hindfoot length, ear length, mass) and reproductive state (e.g., lactating, scrotal). We marked chipmunks with ear tags for future identification purposes.

We fit a 1.6 g or 1.7 g radio collar (model BD-2C; Holohil Systems, Carp, Ontario, Canada) to chipmunks without the use of anesthesia. Radio collars did not exceed 5% of body weight of the chipmunk and were only fit to chipmunks that did not appear stressed and appeared to be in healthy physical condition. We collected a tissue sample by snipping the tip (2 mm) of the external ear pinnae with sharp scissors. We collected ectoparasites using forceps. We collected a sample of feces when possible. We placed radio-collared animals in a recovery container for approximately 30 minutes to help ensure that the collar was not causing the animal discomfort and was not too loose, as well as allowing for full recovery of the animal prior to release. Animals were released as soon as possible near the capture location.

Animal tracking – We located collared chipmunks with a model R-1000 telemetry receiver (Communications Specialists, Orange, CA) attached to a 3-element Yagi antenna (Wildlife Materials International, Inc., Murphysboro, IL) to determine location approximately once every two survey days. A team of two researchers homed to within 10-30m of a chipmunk location. Once a solid fix was obtained, one researcher approached the site while the other researcher continued to track the chipmunk's radio telemetry signal and scan for a visual observation. The homed location was recorded as an original location, and any subsequent visual observations were marked as fleeing locations.

ii. Home range estimation

We identified all temporally independent homed telemetry locations (separated by >2 hours) for every tracked chipmunk. For the home range analysis, we only used individuals with eight or more independent telemetry locations. Using the Minimum Bounding Geometry tool in ArcGIS Pro, we calculated home range size for each chipmunk. We report summary statistics by sex and by subpopulation.

iii. Habitat selection data collection and analysis

Macrohabitat covariate collection – We collected macrohabitat data at 125 used sites and 375 available sites. Used sites were defined as temporally independent homed locations. Locations were considered temporally independent if fixes were separated by at least 2 hours. To define available locations, we combined the home range minimum convex polygons from all chipmunks to create a collective home range for the population and buffered this polygon by 1,146m, which was the observed maximum distance traveled by a chipmunk at our study site (Figure 5). We randomly distributed 375 points within this buffered collective home range and spatially rarefied the used and available locations by 10 m.

Because available land cover data for the study area have very low spatial resolution and are not applicable to the life history of a chipmunk, we created a high resolution land cover map of the study site. We obtained USGS National Agriculture Imagery Program (NAIP) data, which are 4-band imagery with 1 m spatial resolution, for the study area with images from 25 May 2016. To inform an improved land cover classification, we collected ground-truth data points throughout the macrohabitat study area. At each ground-truth data point, we identified and marked the dominant land cover class. Using the ArcGIS Pro Image Classification toolset, we used this ground-truth data and the author's knowledge of the study site to perform a supervised segmented classification of the area. The final classified map had 1 m spatial resolution and included eight classes: dead, dirt, shrub, upper montane conifer, subalpine conifer, herbaceous, deciduous, and rock. Using the final classified map, we defined community classes based on percent cover of conifer forest within a 20 m moving window. We defined three community classes: forest, herbaceous, and mingled forest (Table 10, Figure 5). We estimated proportion of cover for each land cover class within a 20 m, 40 m, and 80 m radius of all used and available sites. At each site, we calculated distance to rock, distance to shrub, distance to live conifer forest, distance to dead forest, and distance to forest.

Using a 10 m spatial resolution digital elevation model (DEM) available through the USDA NRCS GeoSpatial Data Gateway, we created relevant topographic variables at three scales (20 m, 40 m, and 80 m radius moving windows). We calculated terrain ruggedness, heat load index, topographic position index, hillshade, slope, and mean summer NDVI (see Occupancy Methods above).

Microhabitat covariate collection – We collected microhabitat data at 78 used sites and 78 available sites. Used sites were defined as temporally independent homed locations. Locations were considered temporally independent if fixes were separated by at least 2 hours. Available sites were randomly chosen locations close to used sites. Available sites were determined by a random azimuth and distance up to 160m. Using telemetry and tracking data from least chipmunks in Colorado and Montana, we have estimated an average home range size of 2 ha for adult least chipmunks, and 160 m is approximately the diameter of a 2 ha circle (Martinsen 1968, Bergstrom 1988).

At each used site, and at a paired available site, we collected ground cover and plant composition data along four equally spaced 10 m transects that radiated out from the site. Every tree >10 cm DBH within one meter of each transect was counted, identified to species, and assigned to a 10 cm size class. We also counted every boulder (>0.5 m width), every stump (dead tree still rooted <1 m high), and every log (>10 cm diameter) within one meter of each transect.

We measured visual obstruction using a cover pole design modified from Griffith and Youtie (1988) at the used or available site, at 5 m, and at 10 m along each transect. The cover pole was a 1 m pole with 10 cm strips in alternating colors. A strip was considered covered if at least 25% was obstructed from view. We read the cover pole at 1 m eye level from a distance of 5 m. The cover pole was read from the transect, so the center readings and 5 m readings were taken facing towards the site center, while the 10 m readings were taken facing away from the site center. We estimated ground cover using the Daubenmire method, which is a method for estimating ground coverage by species or by class (Daubenmire 1959). We estimated ground cover every 2m along four 10m transects using a 20x50 cm quadrat and classing categories as defined by Daubenmire (1959; 0-5%, 5-25%, 25-50%, 50-75%, 75-95%, >95%). Daubenmire readings were taken from a 1 m height above the ground. Ground cover classes and their hypothesized function for *N. m. atristriatus* are listed in Table 6.

From the used or available site, we recorded distance to and species of the nearest tree >10 cm DBH and the nearest shrub. Within a 10 m radius of the used or available site, we recorded the height and species of the tallest shrub, the height of the tallest boulder, and the height of the tallest log. We measured attributes within a 10 m radius of the used or available site because we hypothesized that detection might be higher at site with flee cover available within this radius. Clarke (1993) found that *Neotamias* will flee approximately 10 m (5.4 ± 0.3m when near their burrows, 11.4 ± 0.7m when outside their home range). Using our original classified map (see Occupancy Study above), we calculated percent conifer cover at a 10 m scale and a 30 m scale for every site.

Statistical analysis – Because the species is essentially unstudied, we wanted to consider a wide range of variables to describe habitat selection at each scale. We initially examined 66 macrohabitat variables across 500 sites (125 used; 375 available). We examined

131 microhabitat variables at 156 sites (78 used; 78 available). Prior to model creation, we screened potential variables for inclusion based on significance in univariate logistic regression, correlation with other variables, and biological interpretability. At the macrohabitat scale, we identified a pool of 8 continuous variables and one categorical variable for inclusion in model selection (Table 10). At the microhabitat scale, we considered the Ice Springs and Lookout Mountain area separately for the model building process. We identified a pool of five variables for Ice Springs and three variables for Lookout Mountain; this was the number of variables that the sample sizes could support (Table 9). None of the final variables were highly correlated (all correlation coefficients <0.7).

Based on our *a priori* hypotheses about competition, predation, food, and habitat type, we developed a suite of statistical models to describe habitat selection at each scale. At the microhabitat scale, we developed a suite of models for each subpopulation. We used multiple logistic regression to compare variables collected at used locations to random locations. At the macrohabitat scale, we included a random intercept for individual chipmunk to account for the unexplained heterogeneity between individuals. We assessed model fit using Akaike's Information Criterion for small sample size (AIC_c) and considered models with $\Delta AIC_c < 2$ as competitive models. When we had ≥ 2 unnested competitive models, we calculated model-averaged parameter estimates and relative importance of each predictor variable across competitive models (Arnold 2010).

C. **Results**

i. Animal collaring and tracking

We fit radio collars to 24 individual chipmunks at Ice Springs and Lookout Mountain (Table 7). Seven chipmunks dropped their collar shortly after being tagged, and one experienced collar failure. We relocated 16 chipmunks at least once via radio telemetry. We found seven chipmunks dead from various causes throughout the study period. All mortalities were reported to the NMDGF Nongame Mammalogist, and methods were reviewed (number of animals collared; trap mortalities; handling/collaring mortalities; recaptures, especially of collared animals; and logistical problems) following the initial application of collars to 10 individuals and following each mortality.

Due to unforeseen logistical difficulties, we were unable to collar animals in the Nogal Peak population. Of the 16 successfully tracked chipmunks, six were in the Lookout Mountain area and 10 were in the Ice Springs area.

ii. Home range estimation

Fourteen of the 16 collared chipmunks had eight or more temporally independent locations, and these 14 chipmunks were used for the analysis (Table 8; Table 9; Figure 4). Mean home range size was 1.59(±1.45) hectares. Mean male home range size was 2.40(±1.67) ha and mean female home range size was 0.77(±0.35) ha. At Ice Springs, the mean home range size was 1.66(±1.71) ha. At Lookout Mountain, the mean home range size was 1.45(±0.77) ha.

We documented one interesting dispersal event. An adult male chipmunk was captured and collared at Ice Springs on 31 May and was relocated at Lookout Mountain on 13 July, having traveled 1,146 m (not accounting for ground distance associated with local topography). Previous to our study, the longest recorded distance traveled by a least chipmunk was 530 m (Meredith 1974).

iii. Macrohabitat results

At the macrohabitat scale, there were four competitive models with $\Delta AIC_c < 2$ (Table 14). We averaged across these four models (Arnold 2010). The final model-averaged model included slope, hillshade, heat load, community class, proportion dead cover, proportion upper montane conifer cover, distance to shrub, and distance to rock (Table 15). We used the final model-averaged model to calculate a map of predicted probability of use for the macrohabitat study area (Figure 6).

iv. Microhabitat results

Ice Springs – At Ice Springs, the top model was the only competitive model, after screening for uninformative parameters (Table 16). This model included large spruce, mean percent gooseberry cover, and vertical cover.

Lookout Mountain – At Lookout Mountain, there were two top models: the global model and the boulder + vertical cover model (Table 17). Because both models were competitive with $\Delta AIC_c < 2$, we model averaged across these two models (Arnold 2010). Boulder and vertical cover had the same relative variable importance, while herbaceous cover was less important (Table 18).

D. Discussion

i. Interpretation

a. Home range

Our mean home range estimate was smaller than the estimate from Bergstrom (1988), which is the only other study to have used radio telemetry data (Table 9). However, Bergstrom's sample size was skewed towards male chipmunks, and our male home range estimate is more comparable to his estimate. Our mean estimate was larger than those derived from visual tracking or trapping grid data. This was as expected; live trap grids tend to underestimate home range size (Bergstrom 1988).

The mean home range size at Lookout Mountain was smaller than that at Ice Springs. Because we trapped first at Ice Springs, the chipmunks in that area were tracked more during the summer months, especially during June and July, which could explain a difference in movement patterns since chipmunks at Lookout Mountain were mostly tracked July through September. On average, we also obtained more locations per individual at Ice Springs, which likely increased home range estimates.

b. Macrohabitat selection

Competition – At the macrohabitat scale, we found evidence for avoidance of upper montane conifer forest and avoidance of the forested community class. These results indicate that competition with *N. canipes* may be a driver of the selection of the location of a home range.

Predation – We found evidence that *N. m. atristriatus* select for home ranges nearer to shrubs and we found weak evidence that *N. m. atristriatus* select for home ranges nearer to rocks, at the macrohabitat scale. This is evidence that predation risk may be influencing the selection of the location of home range.

Food – The evidence showing selection for home ranges nearer to shrubs indicates that food availability, especially of shrubby species, may be important for the species at the macrohabitat scale.

Habitat type – The top model indicates that *N. m. atristriatus* selected for flatter slopes, areas with higher illumination, and areas with more incident radiation. We also found evidence of selection for the mingled forest community class.

The map of predicted probability of use at the macrohabitat scale demonstrates that habitat for *N. m. atristriatus* is patchy and small in area.

c. Microhabitat selection

Competition – At Ice Springs, we found evidence for selection of large spruce trees on the home range scale. At Lookout Mountain, none of the conifer forest-related covariates showed a strong enough influence on selection during univariate tests to be included in the final pool of variables for model selection. These results indicate that we do not have strong evidence for competition as a driver of microhabitat scale selection.

Predation – At Ice Springs, the top model indicated selection for patches with greater mean % gooseberry cover and a greater mean % vertical cover, or visual obstruction. At Lookout Mountain, the model-averaged variable importance indicated strong selection for patches with a higher count of boulders and a greater mean % vertical cover. These results provide a strong indication of the importance of predation as a driver of patch selection within home range in both areas.

Food – At Ice Springs, we detected strong selection for patches with greater mean % gooseberry cover. At Lookout Mountain, we detected negative selection for patches with greater mean % herbaceous cover. The selection for gooseberry cover indicates that food availability may be a driver of patch selection. The negative selection for herbaceous cover is more difficult to interpret. We suspect that the herbaceous cover covariate is describing large monotypic patches, dominated by one or a few species of grasses and forbs. While least chipmunks have been documented to feed on a variety of grass and forb species, it is likely that the plant species appearing in large grassland type patches do not provide the necessary seeds or flowers. Without an experimental study of food preferences, it is difficult to determine why *N. m. atristriatus* is avoiding these large herbaceous patches.

ii. Management implications

The large spruce trees at Ice Springs are 30-60 cm diameter at breast height (DBH). Although DBH is not a perfect correlate for tree age, a study in the Colorado Front Range in similarly structured stands found that Engelmann’s spruce trees in this size class ranged from approximately 175 to 300 years old (Veblen 1986). At the Ice Springs area, the largest DBH trees were commonly associated with meadow openings dominated by gooseberry currant and an abundant matrix of grass and forbs. Furthermore, these large DBH spruce trees often exhibited a different growth form as compared to the smaller DBH trees that occur in dense forest. The large meadow trees have low-lying limbs, providing additional low cover, while the larger trees in the dense forest generally have no low-lying limbs (Figure 7).

At the macrohabitat scale, we found selection for mingled conifer forest (i.e., stands where conifer trees are present at low densities). At the microhabitat scale, we found selection for large DBH spruce trees. Both of these findings indicate the importance of a specific stand structure. These findings support conclusions of Frey and Boykin (2007), who suggested that the potential extirpation of *N. m. atristriatus* in the southern Sacramento Mountains was due, in part, to historical logging and other factors that have changed forest stand conditions. In addition, the map of predicted probability of use at the macrohabitat scale suggests that habitat is patchy and small in area, suggesting the population of *N. m. atristriatus* in the Lookout Mountain-Ice Springs study area may be very small.

Maintaining existing stands of old growth spruce may be very important for *N. m. atristriatus* persistence and potential recovery. Stands of old growth spruce in the Sacramento Mountains are threatened by disease and wildfire. We also found that *N. m. atristriatus* avoided dead forest cover, which reinforces the importance of managing stand-replacing wildfires and forest insect pests. Management practices that mitigate these threats may be vital for the persistence of this rare chipmunk.

We found evidence for selection of home ranges nearer to shrubs on the macrohabitat scale and for selection of patches with gooseberry, boulders, and vertical cover on the microhabitat scale. Escape cover seems to be important for *N. m. atristriatus* on both scales. Overgrazing can eliminate the thick understory that this species is relying on. At sites with potential least chipmunk habitat and of historical occurrence, managing grazing by cattle to rehabilitate the understory is important. At locations where the species is known to persist, cattle are not currently present. However, it is important to consider the potential impacts of grazing by elk and feral horses on these delicate ecosystems (Figure 8).

iii. Mortality discussion

We fitted radio collars to 24 individual chipmunks at Ice Springs and Lookout Mountain. Of those 24 chipmunks, we found seven chipmunks dead from various causes throughout the study period. All mortalities were reported to the NMDGF Nongame Mammalogist and methods were reviewed following each mortality. We had no chipmunks die during trapping or handling. All specimens collected have been deposited at the NMSU Wildlife Museum. We plan to attempt to use the remains of the skulls to age the dead animals.

Description of the 7 chipmunks found dead:

- VIC was alive for at least 60 days following collaring; found dead on day 74 with antenna wire caught in vegetation and body hanging from antenna wire.
- KEN dropped its collar, which was found the next day; found dead on day 36 after initial collaring with body lying on the ground approximately 200 m from where the collar had been previously found (suggesting it had been alive for a while after losing his collar before dying).
- KEV was alive for at least 61 days following collaring; found dead on day 117 decomposed in burrow, which was dug up to determine fate.
- UTA was alive for at least 41 days following collaring; found dead on day 84 above ground and decomposed, with antenna wire frayed and caught in vegetation.
- WLW was alive for at least 12 days following collaring; found dead on day 13 with skin on head pealed back and antenna wire bent across head, suggesting it was possibly scalped by the antenna wire.

- TRI was alive for at least 27 days following collaring; found dead on day 74 decomposed in burrow, which was dug up to determine fate. A dead deer mouse (*Peromyscus maniculatus*) was also found inside the burrow.
- ODD was alive for at least 27 days following collaring; found dead on day 74 decomposed in burrow, which was dug up to determine fate

In addition to these 7 known mortalities, the signal from one chipmunk (BAR) that was known alive for at least 59 days began to repeatedly transmit from up in the same tree starting on day 60. We do not know if this individual died or dropped its collar.

Two, and possibly three, of the chipmunk moralities appear to have been related to the collar antenna. We used Holohil model BD-2C (same model as used for jumping mice and Organ Mountains chipmunks) in the 1.6 and 1.7 g weight with 45 lb-test antennas, which were sized correctly based on recommendations given the mass of these chipmunks. We have not experienced these types of mortalities in other small mammal radio telemetry studies, either with jumping mice (smaller animals but using 0.8 g collars) or with Organ Mountains Colorado chipmunks (larger animals using 1.7 g collars). We suspect the gauge of wire used in these antennas is too stiff for the body mass and strength of *N. m. atristriatus*. In future studies, 15 lb-test, 20 lb-test, or 30 lb-test antennas could be used to alleviate this problem.

More worrisome is finding 4 chipmunks dead for no apparent reason. The only reason we are aware of these deaths was because we could locate the collars, the exception being KEN, which was simply found dead on the ground at Ice Springs. In our experience, it is rare to find dead small mammals simply lying on the ground, but it does happen. In these cases, we usually suspect disease since it is unlikely for a small mammal to live to old age.

The remaining 3 dead chipmunks were all found decomposed inside their burrows at Lookout Mountain. One was found along with a dead *Peromyscus maniculatus* in the same burrow, which strongly suggests the deaths were not due to the collars. There are many possible diseases that circulate in small mammal populations such as Hantavirus, plague, and tularemia. An alternative hypothesis is some type of toxin, such as rodenticides, or some naturally occurring plant or fungus, such as iris. There is also the possibility that heavy machinery used for ski run maintenance crushed the chipmunks inside their burrows, since all three were found on and around the Ski Apache slopes.

*Table 7. Locations, effort, and results for collaring effort for Peñasco least chipmunk (*Neotamias minimus atristriatus*) in 2019. Includes captures of the gray-footed chipmunk (*Neotamias canipes*).*

Descriptive Location	**Survey dates**	**Trap days**	***N. m. atristriatus* captured**	***N. m. atristriatus* collared**	***N. canipes* captured**
Ice Springs	29 May - 1 June	1000	19	15*	0
Monjeau Peak	3-4 June	500	0	0	2
Nogal Trailhead	14-19 June	1920	0	0	4
Ice Springs	2-4 July	720	4	4	1
Lookout Mt	13 July	300	5	5	0
Lookout Mt	8-12 September	1500	3	0**	2
Ice Springs	23-26 September	800	6	0**	1

*Four chipmunks were not collared because we were initially limited to the application of 10 collars, pending review by the NMDGF Nongame Mammalogist.

**No chipmunks were collared in September because collars were being removed during these trapping efforts.

Table 8. Home range estimates of individual Peñasco least chipmunks (Neotamias minimus atristriatus)*. Number of locations is the number of independent homed locations used to estimate home range.*

Unique ID	Sex	Site	Collar date	Last location	Number of locations	Home range area (ha)
AKA	M	Ice Springs	7/2/2019	8/15/2020	12	0.89
BOD	M	Ice Springs	7/3/2019	8/15/2019	12	4.66
BRT	M	Ice Springs	5/31/2019	8/1/2019	13	0.77
BUC	M	Ice Springs	5/30/2019	8/15/2019	16	5.02
STE	M	Ice Springs	5/29/2020	8/15/2019	19	1.01
BAR	F	Ice Springs	5/30/2020	8/1/2019	16	0.37
TAM	F	Ice Springs	5/30/2019	8/15/2019	19	0.54
UTA	F	Ice Springs	7/2/2020	9/23/2019	15	0.94
VIC	F	Ice Springs	5/30/2019	8/12/2019	18	0.77
KEV	M	Lookout Mountain	5/31/2020	9/25/2020	21	2.67
TIM	M	Lookout Mountain	7/13/2019	8/9/2019	8	1.78
ODD	F	Lookout Mountain	7/13/2019	9/25/2019	12	0.66
RIP	F	Lookout Mountain	7/13/2019	9/9/2019	10	0.60
TRI	F	Lookout Mountain	7/13/2019	9/25/2019	12	1.52

Table 9. Summary of home range estimates and summary of estimates for least chipmunks (Neotamias minimus) *reported in the literature.*

		Data type	Sex	N	x̄	Range
our study population	Total	Radio telemetry	both	14	1.59	0.37-5.02
	Male	Radio telemetry	M	7	2.40	0.77-5.02
	Female	Radio telemetry	F	7	0.77	0.37-1.52
	Ice Springs	Radio telemetry	both	9	1.66	0.37-5.02
	Lookout Mountain	Radio telemetry	both	5	1.45	0.60-2.67
literature estimates	Bergstrom (1988)	Radio telemetry	both	4	2.73	1.38-5.42
	Martinsen (1968)	Visual tracking	both	6	1.28	0.85-1.29
	Sheppard (1972)	Trapping grid	F	19	0.66	0.22-1.51
	Sheppard (1972)	Trapping grid	M	10	1.23	0.39-3.47
	Chappell (1978)	Trapping grid	F	8	1.04	--
	Chappell (1978)	Trapping grid	M	13	1.06	--

*Figure 4. Minimum convex polygons estimated for 14 Peñasco least chipmunks (*Neotamias minimus atristriatus*). Males appear in green while females appear in blue.*

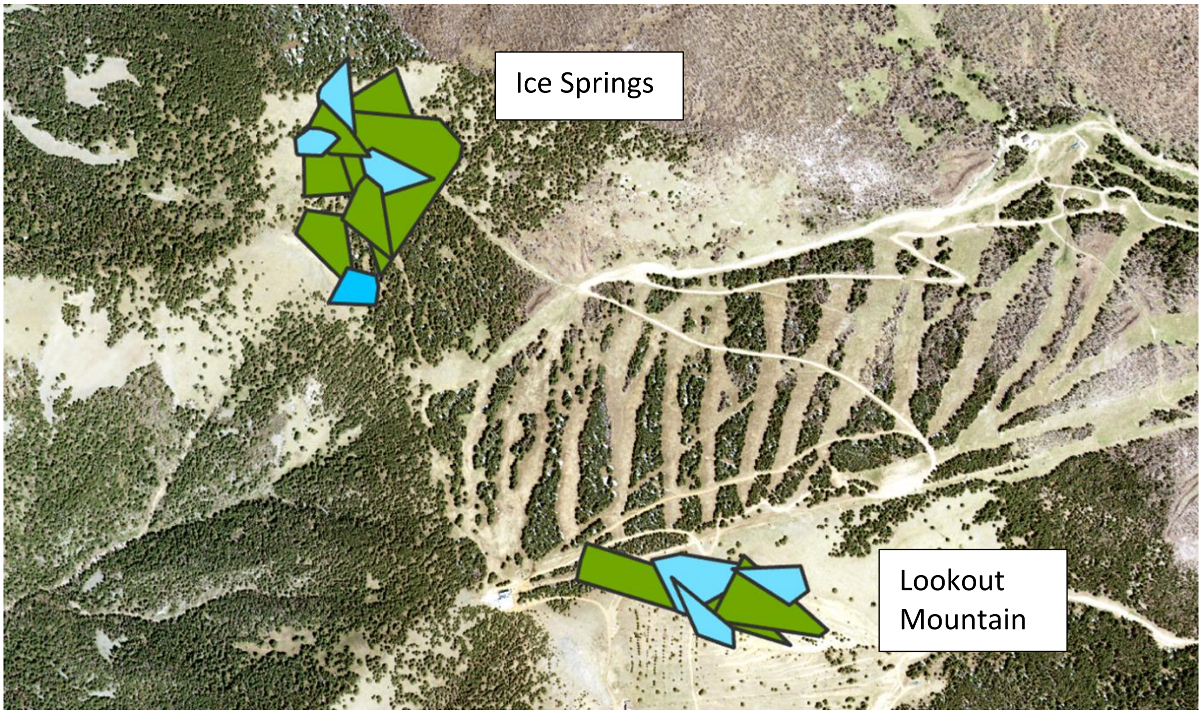


Table 10. Final pool of parameters considered for macrohabitat model selection.

Model parameters		**Parameter definitions**
Community class (categorical)	**forest**	>50% conifer/dead tree cover in a 20 m radius moving window.
	mingled	>0% sparse conifer cover in a 20 m radius moving window. Sparse conifer cover defined as conifer/dead tree cover, excluding areas of forest as defined above, and excluding trees within a 10 m buffer of forest.
	herbaceous	0% conifer/dead tree cover. Note: patches of rock were defined as majority cover surrounding.
Slope		Slope of the terrain, calculated from DEM, using Slope tool in Spatial Analyst Tools ArcGIS Pro.
Hillshade		Relative amount of illumination based on topography, latitude, and sun's position. Ranges from 0 to 255; 0 is darkest and 255 is brightest. Averaged across 9am, 12pm, and 3pm for 2019 solstices and equinoxes. Calculated from DEM, using Hillshade tool in ArcGIS Pro.
Heat load		McCune and Keon Heat Load Index, estimate of potential annual direct incident radiation, depends on latitude, slope, and aspect. Ranges from 0 to 1; 0 is coldest and 1 is warmest. Calculated from DEM, using Heat Load Index tool from Geomorphometry and Gradient Metrics toolbox.
Dead		Proportion dead cover within a 40 m radius. Calculated from classified map.
Montane		Proportion upper montane conifer cover within a 80 m radius. Calculated from classified map.
Herbaceous		Proportion herbaceous cover within a 80 m radius. Calculated from classified map.
Distance to shrub		Distance to nearest shrub. Calculated from classified map.
Distance to rock		Distance to nearest rock. Calculated from classified map.
Distance to live tree		Distance to nearest live tree. Calculated from classified map.

Table 11. Final pool of parameters considered for model selection at the microhabitat scale. X means that the parameter was considered at that site.

Model parameters	**Parameter definitions**	**Ice Springs**	**Lookout Mountain**
Big spruce	count of Engelmann's spruce (*Picea engelmannii*) DBH > 30 cm	X	--
Litter (sd)	standard deviation of % woody litter cover	X	--
Gooseberry	mean % gooseberry (*Ribes montigenum* and *Ribes pinetorum*) cover	X	--
Grass	mean % grass cover	X	--
Vertical cover	mean % visual obstruction below 1 m	X	X
Boulder	count of boulders 0.5 m-5 m wide	--	X
Herbaceous	mean % cover of grass and forbs	--	X

Table 12. Conceptual models for microhabitat selection in the Ice Springs area.

Model number	Model names	Model justification
1	global model	global model
2	big spruce	presence of grey footed chipmunk (*Neotamias canipe*s)
3	litter (standard deviation; sd)	presence of *N. canipes*
4	vertical cover	cover from predators
5	gooseberry	cover from predators; fruits and flowers
6	grass	seeds and flowers
7	big spruce + litter (sd)	presence of *N. canipes*
8	big spruce + gooseberry + grass	presence of *N. canipes*; seeds, fruits and flowers
9	gooseberry + grass	seeds, fruits and flowers
10	big spruce + grass	presence of *N. canipes*; seeds and flowers
11	gooseberry + vertical cover	cover from predators
12	big spruce + gooseberry + vertical cover + grass	cover from predators; cones, seeds, fruits and flowers
13	gooseberry + vertical cover + grass	cover from predators; seeds, fruits and flowers
14	vertical cover + grass	cover from predators; seeds and flowers
15	big spruce + vertical cover + grass	cover from predators; presence of *N. canipes*; seeds and flowers
16	big spruce + litter (sd) + gooseberry + vertical cover	cover from predators; presence of *N. canipes*
17	big spruce + gooseberry + vertical cover	cover from predators; presence of *N. canipes*
18	big spruce + gooseberry	cover from predators; presence of *N. canipes*
19	litter (sd) + gooseberry + vertical cover	cover from predators; presence of *N. canipes*
20	litter (sd) + vertical cover	cover from predators; presence of *N. canipes*
21	big spruce + litter (sd) + vertical cover	cover from predators; presence of *N. canipes*
22	big spruce + vertical cover	cover from predators; presence of *N. canipes*
23	litter (sd) + gooseberry	cover from predators; presence of *N. canipes*
24	big spruce + litter (sd) + gooseberry + grass	presence of *N. canipes*; seeds, fruits and flowers
25	big spruce + litter (sd) + grass	presence of *N. canipes*; seeds and flowers
26	litter (sd) + grass	presence of *N. canipes*; seeds and flowers
27	litter (sd) + gooseberry + grass	presence of *N. canipes*; seeds, fruits and flowers
28	big spruce + litter (sd) + gooseberry	presence of *N. canipes*; fruits and flowers
29	litter (sd) + gooseberry + vertical cover + grass	cover from predators; presence of *N. canipes*; seeds, fruits and flowers
30	big spruce + litter (sd) + vertical cover + grass	cover from predators; presence of *N. canipes*; seeds and flowers
31	litter (sd) + vertical cover + grass	cover from predators; presence of *N. canipes*; seeds and flowers
32		null model

Table 13. Conceptual models for microhabitat selection in the Lookout Mountain area.

Model number	Model names	Model justification
1	global model	global model
2	boulder	cover from predators
3	herbaceous	seeds and flowers
4	vertical cover	cover from predators
5	boulder + herbaceous	cover from predators; seeds and flowers
6	boulder + vertical cover	cover from predators
7	vertical cover + herbaceous	cover from predators; seeds and flowers
8	null model	

Table 14. Macrohabitat model selection table.

Comm-unity Class	dead	distance to shrub	distance to rock	heat load	hill shade	mont-ane	slope	herb	distance to live tree	K	AICc	ΔAICc	AICc wt
+	-5.9	-0.8		-1.3	0.8	-2.5	-1.1			10	294.3	0.0	0.3
+	-6.0	-0.8	-0.2	-1.3	0.9	-2.7	-1.1			11	295.4	1.2	0.2
+	-6.5	-0.7		-0.7		-2.5	-1.2			9	296.1	1.8	0.1
+	-5.5			-1.1	0.7	-2.1	-1.2			9	296.2	1.9	0.1
+	-5.5		-0.2	-1.1	0.9	-2.2	-1.1			10	297.2	2.9	0.1
+	-6.0			-0.6		-2.1	-1.2			8	297.3	3.0	0.1
+	-6.6	-0.7	0.0	-0.7		-2.5	-1.2			10	298.1	3.8	0.0
+	-6.1		-0.1	-0.6		-2.2	-1.2			9	299.2	5.0	0.0
	-6.6	-0.8		-1.6	1.3	-4.4	-1.3	-1.0		9	299.5	5.2	0.0
	-6.7	-0.8	-0.1	-1.6	1.4	-4.5	-1.3	-0.9		10	301.1	6.8	0.0
	-6.3			-1.5	1.3	-4.3	-1.4	-1.1		8	302.2	7.9	0.0
+	-5.7				-0.1	-2.0	-1.4			8	302.7	8.4	0.0
	-6.3		-0.1	-1.5	1.3	-4.3	-1.4	-1.1		9	303.9	9.7	0.0
+	-5.7		-0.2		0.0	-2.1	-1.4			9	304.0	9.7	0.0
+	-6.0	-0.5	-0.2		0.0	-2.3	-1.3			10	304.0	9.8	0.0
	-7.2	-0.9		-0.7		-4.1	-1.4	-0.7		8	307.6	13.3	0.0
+	-6.5			-1.1	0.7		-1.2			8	308.8	14.5	0.0
	-7.1	-0.9	0.1	-0.7		-4.0	-1.4	-0.7		9	309.5	15.3	0.0
	-6.7			-0.6		-3.9	-1.5	-0.9		7	311.0	16.8	0.0
	-6.7		0.1	-0.6		-3.9	-1.5	-0.9		8	312.7	18.5	0.0
	-6.3	-0.7			0.2	-3.7	-1.6	-0.6		8	313.9	19.6	0.0
	-6.0				0.3	-3.6	-1.6	-0.8		7	315.5	21.2	0.0
+	-6.9				0.0		-1.4			7	315.5	21.3	0.0
	-6.3	-0.7	-0.1		0.2	-3.8	-1.6	-0.6		9	315.7	21.4	0.0

+	-6.5	-1.0	-0.3	-1.9	1.2	-2.6				10	316.2	21.9	0.0
	-4.5			-1.0	0.9	-2.0	-1.2			7	316.5	22.2	0.0
+	-6.3	-1.0		-1.8	1.1	-2.4				9	316.9	22.7	0.0
	-6.0		-0.1		0.3	-3.7	-1.6	-0.8		8	317.4	23.1	0.0
	-5.1			-0.4		-2.1	-1.3			6	320.1	25.9	0.0
+	-6.2		-0.3	-1.6	1.1	-2.1				9	321.0	26.8	0.0
+	-5.9			-1.6	0.9	-1.9				8	322.3	28.0	0.0
	-4.7				0.1	-2.0	-1.4			6	322.8	28.6	0.0
	-6.5	-1.1		-2.1	1.4	-3.4		-0.6		8	328.7	34.5	0.0
	-6.7	-1.1	-0.2	-2.0	1.5	-3.5		-0.5		9	328.8	34.6	0.0
+				-1.3	1.1		-1.3		-4.1	8	330.6	36.4	0.0
+		0.2		-1.3	1.1		-1.3		-4.2	9	332.3	38.0	0.0
+		0.2		-1.3	1.1		-1.3		-4.2	9	332.3	38.0	0.0
+		0.2	0.1	-1.3	1.1		-1.3		-4.3	10	334.2	40.0	0.0
				-1.1	1.0		-1.2	0.9	-5.0	7	337.2	43.0	0.0
	-6.2			-1.9	1.4	-3.1		-0.8		7	337.4	43.2	0.0
	-6.4		-0.2	-1.9	1.5	-3.2		-0.7		8	337.6	43.4	0.0
+	-7.0			-1.7	1.0					7	337.7	43.5	0.0
+				-0.4			-1.5		-4.0	7	338.8	44.5	0.0
+			0.2	-0.4			-1.5		-4.3	8	339.0	44.7	0.0
		-0.2		-1.1	1.0		-1.2	1.0	-4.9	8	339.0	44.7	0.0
			0.0	-1.1	1.0		-1.2	0.9	-5.0	8	339.3	45.0	0.0
+		0.4		-0.4			-1.5		-4.2	8	339.7	45.4	0.0
+		0.3	0.2	-0.4			-1.5		-4.5	9	340.2	46.0	0.0
		-0.2	0.0	-1.1	1.0		-1.2	1.0	-4.9	9	341.0	46.8	0.0
+					0.2		-1.5		-3.9	7	341.3	47.0	0.0
+		0.4			0.2		-1.6		-4.2	8	341.8	47.6	0.0
				-0.3			-1.3	1.1	-5.1	6	342.5	48.3	0.0
+			0.1		0.1		-1.6		-4.1	8	342.7	48.5	0.0
+		0.4	0.1		0.1		-1.6		-4.3	9	343.5	49.3	0.0
					0.1		-1.4	1.1	-4.9	6	343.6	49.4	0.0
			0.1	-0.3			-1.3	1.1	-5.2	7	344.3	50.1	0.0
		-0.2		-0.3			-1.3	1.1	-5.1	7	344.4	50.2	0.0
	-5.0			-1.5	1.1	-1.7				6	345.1	50.8	0.0
		-0.1			0.1		-1.4	1.1	-4.9	7	345.7	51.4	0.0
			0.0		0.2		-1.4	1.1	-4.9	7	345.7	51.4	0.0
		-0.2	0.1	-0.3			-1.3	1.1	-5.1	8	346.2	52.0	0.0
+	-6.7	-0.6	-0.3			-2.1				8	349.2	54.9	0.0
+	-6.5		-0.3			-1.9				7	350.3	56.0	0.0
+		-0.7	-0.1	-1.0	1.2	-1.9	-1.3			10	350.7	56.5	0.0
+	-6.1	-0.6				-1.8				7	351.4	57.1	0.0
+	-5.9					-1.7				6	352.4	58.2	0.0

+				-0.9	1.2	-1.4	-1.4			8	353.5	59.3	0.0
+					0.5	-1.4	-1.5			7	358.0	63.8	0.0
+		-0.7	0.0	-0.1		-1.8	-1.4			9	360.0	65.8	0.0
				-1.6	1.6		-1.3		-3.4	6	363.3	69.0	0.0
+				0.0		-1.3	-1.5			7	363.3	69.1	0.0
+				-1.1	1.1		-1.4			7	363.5	69.3	0.0
+		-0.4		-1.1	1.2		-1.3			8	363.5	69.3	0.0
		0.2	0.2	-1.6	1.4		-1.4		-3.9	8	364.7	70.5	0.0
+				-1.1	1.1		-1.3			6	366.0	71.7	0.0
		-1.0		-1.1	1.3	-1.9	-1.2	0.3		8	366.2	72.0	0.0
		-1.0	-0.1	-1.1	1.3	-2.0	-1.2	0.4		9	367.9	73.7	0.0
+				-2.0	1.6				-4.6	7	369.0	74.8	0.0
+		-0.6	0.0	-0.3			-1.3	0.6		9	369.1	74.8	0.0
	-5.9	-0.9				-2.2				5	369.1	74.8	0.0
		-0.9	0.0	-1.1	1.5	-2.4	-1.3			8	369.1	74.8	0.0
+		-0.4	0.0		0.2		-1.4	0.6		9	369.6	75.4	0.0
	-6.2	-1.0	-0.2			-2.2		0.1		7	370.4	76.1	0.0
+			-0.1	-2.0	1.6				-4.4	8	370.5	76.2	0.0
	-5.8	-0.9				-2.0		0.1		6	371.0	76.7	0.0
+		-0.1		-2.0	1.6				-4.5	8	371.1	76.8	0.0
+					0.3		-1.5			6	371.1	76.9	0.0
		-0.6		-1.7	1.4			1.1	-5.1	7	371.9	77.6	0.0
+		-0.3			0.3		-1.5			7	372.2	77.9	0.0
				-1.7	1.3			1.1	-5.5	6	372.3	78.1	0.0
		-0.5	-0.2	-1.8	1.5			1.2	-4.9	8	372.3	78.1	0.0
+		-0.1	-0.1	-2.0	1.7				-4.4	9	372.5	78.3	0.0
			-0.2	-1.7	1.4			1.1	-5.4	7	372.7	78.4	0.0
+		-0.4		-0.2			-1.5			7	372.9	78.7	0.0
+				-0.2			-1.5			6	373.0	78.8	0.0
		-0.9	-0.1		0.5	-1.9	-1.3	0.4		8	375.1	80.8	0.0
				-1.0	1.5	-1.8	-1.4			6	376.3	82.0	0.0
		-0.8	0.0		0.6	-2.4	-1.4			7	378.2	83.9	0.0
	-5.9		-0.2			-2.1		-0.1		6	378.3	84.1	0.0
	-5.6					-1.9		-0.1		5	378.5	84.3	0.0
		-1.0	0.0	-0.1		-1.7	-1.3	0.5		8	379.0	84.8	0.0
		-0.8		-1.1	1.1		-1.1	0.8		7	379.8	85.5	0.0
		-0.8	0.0	-1.1	1.2		-1.1	0.8		8	381.8	87.6	0.0
		0.4	0.3		0.3		-1.7		-3.4	7	383.0	88.7	0.0
		0.4	0.3		0.3		-1.7		-3.4	7	383.0	88.7	0.0
					0.7	-1.9	-1.5			5	383.8	89.6	0.0
					0.4		-1.7		-2.9	5	384.2	89.9	0.0
				-0.4			-1.6		-3.1	5	384.2	90.0	0.0

				-1.0	1.2		-1.2	0.6		6	385.9	91.7	0.0
		-0.8			0.3		-1.3	0.9		6	387.5	93.2	0.0
		-0.9		-0.2			-1.3	0.9		6	388.4	94.2	0.0
					0.4		-1.4	0.7		5	392.9	98.7	0.0
						-3.5			-4.9	4	392.9	98.7	0.0
+		-1.1	-0.1	-1.5	1.7	-1.7				9	394.9	100.6	0.0
				-0.1			-1.4	0.8		5	396.8	102.5	0.0
				0.1		-1.8	-1.6			5	398.7	104.4	0.0
		-0.5		-1.5	1.6		-1.3			6	399.7	105.5	0.0
		-0.5	0.2	-1.4	1.5		-1.3			7	400.7	106.4	0.0
				-1.4	1.6		-1.4			5	400.9	106.7	0.0
+		-1.0	-0.2	-1.6	1.4			0.8		9	402.7	108.5	0.0
								1.4	-5.2	4	403.8	109.5	0.0
		-0.4						1.5	-4.9	5	404.1	109.9	0.0
			-0.1					1.5	-5.2	5	404.7	110.4	0.0
		-0.4	-0.1					1.5	-4.9	6	405.1	110.8	0.0
		-1.4	-0.2	-1.5	1.7	-1.5		0.7		8	407.1	112.8	0.0
	-8.7									3	408.0	113.8	0.0
+				-1.3	1.6	-1.1				7	409.2	114.9	0.0
+		-0.8		-1.7	1.6					7	412.7	118.4	0.0
				-2.4	2.0				-3.8	5	415.5	121.3	0.0
		-0.4	0.2		0.4		-1.6			6	417.2	122.9	0.0
					0.5		-1.6			4	417.3	123.0	0.0
		-1.2		-1.6	1.5			1.0		6	418.5	124.2	0.0
		-0.1	0.1	-2.3	1.9				-3.8	7	418.9	124.7	0.0
		-0.6	0.3	-0.3			-1.5			6	419.5	125.2	0.0
+				-1.5	1.5					6	420.1	125.9	0.0
		-1.3	0.0	-1.6	1.9	-2.2				7	420.8	126.5	0.0
+									-3.8	5	422.4	128.2	0.0
+			0.1						-3.8	6	424.2	129.9	0.0
+		0.1							-3.9	6	424.3	130.1	0.0
							-1.6			3	424.5	130.3	0.0
+		0.1	0.1						-3.9	7	426.1	131.9	0.0
				-0.1			-1.6			4	426.3	132.0	0.0
+		-0.9				-1.7				6	428.2	133.9	0.0
+		-0.9	0.0			-1.7				7	430.2	136.0	0.0
+						-0.7		0.7		6	434.4	140.1	0.0
		-1.2				-1.2		0.9		5	437.4	143.2	0.0
				-1.4	1.5			0.8		5	438.7	144.4	0.0
		-1.2	-0.1			-1.2		0.9		6	439.2	145.0	0.0
				-1.4	2.0	-1.5				5	443.7	149.4	0.0
		-1.1						1.2		4	449.5	155.2	0.0

		-1.1	0.0					1.3		5	451.4	157.1	0.0
+		-0.5								5	457.0	162.7	0.0
+		-0.5	0.1							6	458.2	163.9	0.0
+										4	461.8	167.5	0.0
+			0.1							5	462.9	168.7	0.0
						-0.7		1.0		4	465.2	170.9	0.0
		-0.9	0.2	-2.0	1.9					6	465.5	171.3	0.0
			0.0			-0.7		1.0		5	467.2	173.0	0.0
								1.1		3	470.2	175.9	0.0
			0.0					1.1		4	472.2	177.9	0.0
		-1.2				-2.2				4	472.2	178.0	0.0
		-1.2	0.1			-2.1				5	472.7	178.5	0.0
				-1.9	2.1					4	477.5	183.3	0.0
		-0.1	0.3						-2.3	5	512.2	217.9	0.0
			0.2			-1.3				4	514.7	220.5	0.0
									-2.3	3	516.6	222.3	0.0
						-1.4				3	517.6	223.3	0.0
		0.0							-2.2	4	518.6	224.3	0.0
		-0.7	0.3							4	540.6	246.4	0.0
					0.5					3	547.5	253.2	0.0
		-0.7								3	548.0	253.8	0.0
			0.3							3	557.3	263.0	0.0
				-0.3						3	561.4	267.2	0.0

Table 15. Model averaging results for macrohabitat selection.

	parameter estimate	**SE**	**p-value**	**relative variable importance**
Community class	-	-	-	1.00
slope	-1.12	0.25	0.00	1.00
hillshade	0.68	0.50	0.18	0.83
heat load	-1.18	.47	0.01	1.00
dead	-5.95	1.57	0.00	1.00
montane	-2.48	.75	0.00	1.00
distance to shrub	-0.63	.46	0.17	0.84
distance to rock	-0.05	0.13	0.72	0.24

Table 16. Microhabitat model selection table for the Ice Springs area.

Model name	big spruce	litter (std dev)	vertical cover	goose-berry	grass	K	AICc	ΔAICc	AICc wt
big spruce + gooseberry + vertical cover	0.64		0.65	0.70		4	107.19	0.00	0.27
big spruce + litter (sd) + gooseberry + vertical cover	0.58	0.23	0.72	0.61		5	108.84	1.65	0.12
big spruce + gooseberry + vertical cover + grass	0.58		0.74	0.60	-0.20	5	108.96	1.76	0.11
gooseberry + vertical cover			0.66	0.87		3	110.25	3.05	0.06
big spruce + vertical cover + grass	0.62		1.00		-0.47	4	110.40	3.21	0.05
litter (sd) + gooseberry + vertical cover		0.39	0.77	0.67		4	110.48	3.29	0.05
gooseberry + vertical cover + grass			0.81	0.66	-0.38	4	110.52	3.33	0.05
big spruce + litter (sd) + vertical cover	0.64	0.46	0.95			4	110.84	3.65	0.04
big spruce + gooseberry	0.64			0.92		3	110.86	3.67	0.04
global model	0.56	0.16	0.74	0.58	-0.10	6	111.06	3.87	0.04
big spruce + vertical cover	0.82		0.87			3	111.60	4.41	0.03
big spruce + litter (sd) + vertical cover + grass	0.60	0.22	1.00		-0.32	5	112.29	5.10	0.02
litter (sd) + gooseberry + vertical cover + grass		0.24	0.82	0.63	-0.22	5	112.35	5.16	0.02
big spruce + gooseberry + grass	0.67			0.95	0.08	4	112.94	5.75	0.02
vertical cover + grass			1.08		-0.68	3	113.03	5.84	0.01
big spruce + litter (sd) + gooseberry	0.64	0.00		0.92		4	113.04	5.85	0.01
litter (sd) + vertical cover		0.67	1.01			3	113.83	6.64	0.01
gooseberry				1.07		2	114.34	7.15	0.01
litter (sd) + vertical cover + grass		0.33	1.07		-0.44	4	114.41	7.22	0.01
big spruce + litter (sd) + gooseberry + grass	0.66	0.11		0.94	0.16	5	115.09	7.90	0.01
litter (sd) + gooseberry		0.18		0.98		3	116.00	8.81	0.00
gooseberry + grass				1.01	-0.11	3	116.27	9.08	0.00
litter (sd) + gooseberry + grass		0.19		0.99	0.02	4	118.18	10.99	0.00
vertical cover			0.89			2	119.48	12.29	0.00
big spruce	0.89					2	122.20	15.00	0.00
big spruce + litter (sd)	0.77	0.27				3	123.05	15.85	0.00
big spruce + grass	0.79				-0.25	3	123.17	15.98	0.00
big spruce + litter (sd) + grass	0.76	0.18			-0.13	4	125.07	17.88	0.00
litter sd		0.51				2	128.83	21.64	0.00
grass					-0.48	2	129.33	22.14	0.00
litter (sd) + grass		0.33			-0.24	3	130.35	23.16	0.00
null model						1	132.36	25.16	0.00

*Parameter estimates are non-backtransformed beta estimates for standardized variables. Positive values indicate a positive relationship to probability of use.

Table 17. Microhabitat model selection table for the Lookout Mountain area.

Model names	boulder	vertical cover	herbaceous	**K**	**AICc**	**ΔAICc**	**AICc wt**
global model	0.78	0.9	-0.55	4	75.9	0	0.53
boulder + vertical cover	0.83	0.95		3	76.86	0.96	0.33
vertical cover + herbaceous		0.79	-0.61	3	79.78	3.88	0.08
boulder + herbaceous	0.64		-0.65	3	81.99	6.09	0.03
vertical cover		0.81		2	82.12	6.22	0.02
herbaceous			-0.66	2	84.49	8.59	0.01
boulder	0.68			2	84.58	8.68	0.01
null				1	88.02	12.12	0

*Parameter estimates are non-backtransformed beta estimates for standardized variables. Positive values indicate a positive relationship to probability of use.

Table 18. Model averaging results for microhabitat selection in the Lookout Mountain area.

	Parameter estimate	**SE**	**p-value**	**relative variable importance**
boulder	0.80	0.35	0.03	1.00
vertical cover	0.92	0.35	0.01	1.00
herbaceous	-0.34	0.37	0.36	0.62

Figure 5. Map of macrohabitat study area shown in red on left-hand map. Right-hand map shows community classes. Forest is shown in green; herbaceous is shown in yellow; mingled is shown in purple.

Figure 6. Map of predicted probability of use at the macrohabitat scale calculated from model-averaged macrohabitat model. Green represents a probability of 0; red represents a probability of 1.

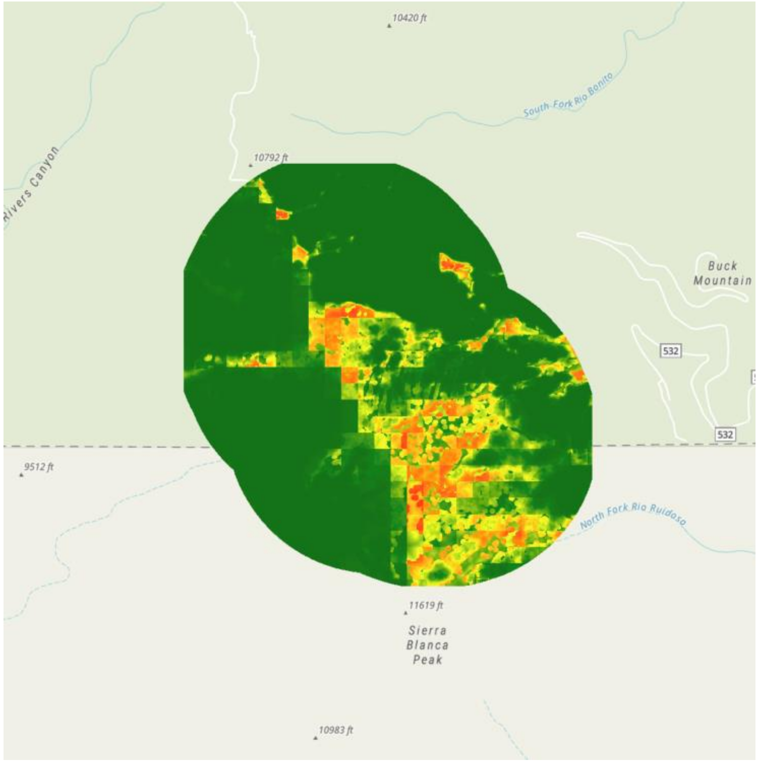


Figure 7. Two images of spruce forest taken in the Ice Springs area. The image to the left shows sparse spruce, occurring interspersed with small meadow patches containing Ribes shrubs, while the image on the right shows a dense spruce forest. Note the differences in growth form (i.e., low limbs present in the sparse spruce forest).

Figure 8. A herd of feral horses grazing at Monjeau Peak, within the study area.

V. Conclusions and Future Work

A. Key Management Implications

At the macrohabitat scale, we found evidence of the importance of mingled conifer forest, while at the microhabitat scale we found evidence of the importance of large spruce trees. Maintaining old growth stands of spruce may be very important for species persistence and recovery. These stands are threatened by disease (i.e., spruce bark beetle) and wildfire, both of which are accelerated by changing climate. Mitigating both threats may be important for the persistence of *N. m. atristriatus* throughout its current known distribution.

We also found strong evidence that vertical cover and shrubby cover are important to the *N. m. atristriatus*. This vertical cover is provided by gooseberry shrubs and other understory species. Managers should consider the impacts of grazing by cattle, elk, and feral horses on the shrubby matrix.

Finally, we found evidence of negative selection for herbaceous cover. We believe this variable describes large monotypic patches of grass (i.e., subalpine-montane grasslands). While previous studies have described least chipmunks as a “meadow” species, there is a distinction between small meadow openings and edges as opposed to large monotypic grasslands (Vaughn 1974, Meredith 1976, Dick-Peddie 1993). Large patches of subalpine-montane grassland do not constitute least chipmunk habitat.

B. Future work

We plan to complete the model selection process for our occupancy analysis by late April 2020. Fiona McKibben will complete and defend her thesis before August 2020. This thesis will be submitted to the agency. Findings will be submitted for publication as three separate manuscripts focused on identification methods, occupancy analysis, and radio telemetry.

VI. Literature Cited

Bailey, V. 1931. Mammals of New Mexico. North American Fauna 53:1-412.

Bergstrom, B. J. 1988. Home ranges of three species of chipmunks (*Tamias*) as assessed by radiotelemetry and grid trapping. Journal of Mammalogy 69(1):190-193.

Bergstrom, B.J., and R. S. Hoffman. 1991. Distribution and diagnosis of three species of chipmunks (*Tamias*) in the front range of Colorado. The Southwestern Naturalist 36:14-28.

Bihr, K. J., and R. J. Smith. 1998. Location, structure, and contents of burrows of *Spermophilus lateralis* and *Tamias minimus*, two ground-dwelling sciurids. The Southwestern Naturalist 43:352-362.

Carleton, W. M. 1966. Food habits of two sympatric Colorado sciurids. Journal of Mammalogy 47:91-103.

Chappell, M. A. 1978. Behavioral factors in the altitudinal zonation of chipmunks (*Eutamias*). Ecology 59(3):565-579.

Ciarniello, L. M., M.S. Boyce, D.R. Seip, and D.C. Heard. 2007. Grizzly bear habitat selection is scale dependent. Ecological Applications 17(5):1424-1440.

Daubenmire, R. F. 1959. A canopy-cover method of vegetational analysis. Northwest Science 33:43-46.

Davis, F. W., and S. Goetz. 1990. Modeling vegetation pattern using digital terrain data. Landscape Ecology 4(1):69-80.

De Bondi, N., J. G. White, M. Stevens, and R. Cooke. 2010. A comparison of the effectiveness of camera trapping and live trapping for sampling terrestrial small-mammal communities. Wildlife Research 37:456-465

Dick-Peddie, W. A. 1993. New Mexico vegetation, past, present, and future. University of New Mexico Press, Albuquerque, NM.

Frey, J. K. 2016. Survey for the Peñasco least chipmunk (*Tamias minimus atristriatus*). Share with Wildlife Program, New Mexico Game and Fish. Interim Report, Professional Services Contract #16516000000031.

Frey, J. K., and K. Boykin. 2007. Status assessment of the Peñasco least chipmunk (*Tamias minimus atristriatus*). Final Report submitted to New Mexico Department of Game and Fish, Santa Fe, 30 June 2007, 72 pp. + appendices on CD.

Frey, J. K., and Q. R. Hays. 2017. Surveys for the Peñasco least chipmunk 2016. Final Report submitted to Share with Wildlife, Conservation Services Division, New Mexico Department of Game and Fish, March 2017, 53 pp.

Frey, J. K., and F. E. McKibben. 2018. Distribution, abundance, and habitat selection by the Peñasco least chipmunk (*Neotamias minimus atristriatus*) 2018. Final Report submitted to New Mexico Department of Game and Fish, Share with Wildlife Program, Santa Fe, 19 December 2018.

Griffith, B., and B. A. Youtie. 1988. Two devices for estimating foliage density and deer hiding cover. Wildlife Society Bulletin 16(2):206-210.

Hadley, G. L., and K. R. Wilson. 2004. Patterns of small mammal density and survival following ski-run development. Journal of Mammalogy 85:97-104.

Hope, A. G., and J. K. Frey. 2000. Survey for the Peñasco least chipmunk (*Tamias minimus atristriatus*) in the Lincoln National Forest with notes on rodent community assemblages. Final Report submitted to Lincoln National l Forest, Alamogordo, New Mexico. 48 pp.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61(1):65-71.

Kery, M., and M. Schaub. 2012. Bayesian Population Analysis using WinBUGS: A hierarchical perspective. Elsevier Inc. Ch. 13: 413-461.

Linkie, M., Y. Dinata, A. Nugroho, and I. A. Haidir. 2007. Estimating occupancy of a data deficient mammalian species living in tropical rainforests: Sun bears in the Kerinci Seblat region, Sumatra. Biological Conservation 137:20-27.

Mackenzie, D.I., J. Nichols, J. Royle, K. Pollock, L. Bailey, and J. Hines. 2018. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Elsevier Inc., London.

Martinsen, D.L. 1968. Temporal patterns in the home ranges of chipmunks (*Eutamias*). Journal of Mammalogy 49:83-91.

Meredith, D.H. 1976. Habitat selection by two parapatric species of chipmunks (*Eutamias*). Canadian Journal of Zoology 54:536-543.

Nagorsen, D. 2004. Status of the least chipmunk (*Tamias minimus*) subspecies *T. m. oreocetes* and *T. m. selkirki* in British Columbia. Wildlife Working Report No. WR 116.

Newkirk, E. S. 2016. CPW Photo Warehouse. Colorado Parks and Wildlife, Fort Collins, Colorado, USA. http://cpw.state.co.us/learn/Pages/ResearchMammalsSoftware.aspx

New Mexico Department of Game and Fish. 2016. Threatened and endangered species of New Mexico 2016 Biennial Review. NMDGF Wildlife Management and Fisheries Management Divisions, 5 October 2016, pages 4-6.

O'Neill, R. V. 1989. Perspectives in hierarchy and scale. Pp 140-156 *in* J. Roughgarden, R. M. May and S. A. Levin, editors. Perspectives in ecological theory. Princeton University Press, Princeton, N.J., USA.

Ortiz, D. M. 1999. The determination of the existence and predominant habitat of the Peñasco Least Chipmunk (*Tamias minimus atristriatus*) in the Sacramento Mountain region of New Mexico throughout June and July of 1998. Research investigation presented as a requirement for attaining the degree of Baccalaureate of Science with specialization in Environmental Science. Univ. of Puerto Rico, Rio Piedras Campus, Environmental Science Prog. 29 pp

Perkins-Taylor, I., and J. K. Frey. 2018. Ecological factors associated with site occupancy of an endemic chipmunk. Journal of Wildlife Management 82(7):1466-1477.

Peterson, M. E., C. E. Rebar, K. S. Eisenhart, and D. I. Stetson. 2017. Responses of small mammal communities to pinyon-juniper habitat treatments. Western North American Naturalist 77(3):331-342.

Poffenroth, M., and J. O. Matson. 2007. Habitat partitioning by two sympatric species of chipmunk (Genus: *Neotamis*) in the Warner Mountains of California. Bulletin of Southern California Academy of Sciences 106(3):208-214.

Rodhouse, T. J., R. P. Hirnyck, and R. G. Wright. 2010. Habitat selection of rodents along a pinon-juniper woodlandsavannah gradient. Journal of Mammalogy 91(2):447-457.

Root, J. J., C.H. Calisher, and B.J. Beaty. 2001. Microhabitat partitioning by two chipmunk species (*Tamias*) in western Colorado. Western North American Naturalist 61(1):114-118.

Schmidt, K. A., E. Lee, R. S. Ostfeld, and K. Sieving. 2008. Eastern chipmunks increase their perception of predation risk in response to titmouse alarm calls. Behavioral Ecology 19(4):759-763.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of Sample Size on Kernel Home Range Estimates. The Journal of Wildlife Management 63(2):739-747.

Sheppard, D. H. 1971. Competition between two chipmunk species (*Eutamias*). Ecology 52(2):320-329.

Sikes, R. S. and The Animal Care and Use Committee of the American Society of Mammalogists. 2016. 2016 guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. Journal of Mammalogy 97(3):663-688

Sternberg, M. and M. Shoshany. 2001. Influence of slope aspect on Mediterranean woody formations: comparison of a semiarid and an arid site in Israel. Ecological Research 16:335-345.

Storm, J. J., and J. R. Choate. 2012. Structure and movements of a community of small mammals along a powerline right-of-way in subalpine coniferous forest. The Southwestern Naturalist 57(4):385-392.

Svendsen, G. E. 1974. Behavioral and Environmental Factors in the Spatial Distribution and Population Dynamics of a Yellow-Bellied Marmot Population. Ecology 55(4): 760-771.

Thorn, M., D. M. Scott, M. Green, P. W. Bateman, and E. Z. Cameron. 2008. Estimating brown hyena occupancy using baited camera traps. South African Journal of Wildlife Research 39:1-10.

U.S. Fish and Wildlife Service. 2014. Review of native species that are candidates for listing as endangered or threatened; Findings for petitioned candidate species. Federal Register 79(234):72450-72497.

Vaughn, T.A. 1974. Resource allocation in some sympatric, alpine rodents. Journal of Mammalogy 55:764-795.

Veblen, T. T. 1986. Age and size structure of subalpine forests in the Colorado front range. Bulletin of the Torrey Botanical Club 113(3):225-240.

Wampler, C. R., J. K. Frey, D. M. Van Leeuwen, J. C. Boren, and T. T. Baker. 2008. Mammals in mechanically thinned and non-thinned mixed-coniferous forest in the Sacramento Mountains, New Mexico. The Southwestern Naturalist 53:431-443.

Wright, G. D., and J. K. Frey. 2015. Habitat selection by the endangered New Mexico meadow jumping mouse on an Irrigated Floodplain. Journal of Fish and Wildlife Management 6(1): 112-129.

Yahner, R. H., and G. E. Svendsen. 1978. Effects of climate on the circannual rhythm of the eastern chipmunk, *Tamias striatus*. Journal of Mammalogy 59(1):109-117.

Yandow, L. H., A. D. Chalfoun, and D. F. Doak. 2015. Climate tolerances and habitat requirements jointly shape the elevational distribution of the American pika (*Ochotona princeps*), with implications for climate change effects. PLoS One 10(8): e0131082. doi:10.1371/journal.pone.0131082.

VII. Supplemental Material: Camera Deployment

Table 19. Sites sampled between 2 June and 28 July, stratified by habitat type and by elevation. Detected chipmunks are of unknown species.

Descriptive Location	Unique site ID	Date of first survey	Chipmunk detected on camera
Buck Mountain	233	2-Jun	--
Buck Mountain	237	2-Jun	--
Buck Mountain	239	2-Jun	--
Buck Mountain	246	2-Jun	--
Buck Mountain	253	2-Jun	--
Buck Mountain	254	2-Jun	--
Buck Mountain	257	2-Jun	--
Buck Mountain	258	2-Jun	--
Buck Mountain	263	2-Jun	--
Buck Mountain	264	2-Jun	--
Buck Mountain	266	2-Jun	--
Buck Mountain	267	2-Jun	--
Buck Mountain	277	2-Jun	--
Buck Mountain	286	2-Jun	--
Buck Mountain	287	2-Jun	--
Buck Mountain	289	2-Jun	--
Nogal Canyon/FS 400	6	13-Jun	Yes
Nogal Canyon/FS 401	8	13-Jun	--
Nogal Canyon/FS 402	9	13-Jun	--
Nogal Canyon/FS 403	13	13-Jun	--
Nogal Canyon/FS 404	17	13-Jun	--
Nogal Canyon/FS 405	18	13-Jun	--
Nogal Canyon/FS 406	20	13-Jun	--
Nogal Canyon/FS 407	21	13-Jun	--
Nogal Canyon/FS 408	44	13-Jun	Yes
Nogal Canyon/FS 409	53	13-Jun	--
Nogal Canyon/FS 410	60	13-Jun	--
Nogal Canyon/FS 411	61	13-Jun	--
Nogal Canyon/FS 412	66	13-Jun	--
Nogal Canyon/FS 413	67	13-Jun	--
Nogal Canyon/FS 414	70	13-Jun	--
Nogal Canyon/FS 415	155	13-Jun	Yes
Nogal Canyon/FS 416	192	13-Jun	--
Nogal Canyon/FS 417	199	13-Jun	--

Nogal Canyon/FS 418	200	13-Jun	Yes
Nogal Canyon/FS 419	201	13-Jun	--
Nogal Canyon/FS 420	202	13-Jun	--
Nogal Canyon/FS 421	209	13-Jun	Yes
Nogal Canyon/FS 422	211	13-Jun	--
Nogal Canyon/FS 423	214	13-Jun	--
Nogal Canyon/FS 424	218	13-Jun	--
Nogal Canyon/FS 425	221	13-Jun	--
Ice Springs	243	27-Jun	--
Ice Springs	249	27-Jun	--
Ice Springs	268	27-Jun	yes
Ice Springs	269	27-Jun	yes
Ice Springs	297	27-Jun	yes
Ice Springs	303	27-Jun	--
Ice Springs	304	27-Jun	--
Ice Springs	309	27-Jun	yes
Ice Springs	312	27-Jun	yes
Ice Springs	315	27-Jun	yes
Ice Springs	321	27-Jun	--
Ice Springs	369	27-Jun	--
Ice Springs	371	27-Jun	--
Ice Springs	372	27-Jun	--
Ice Springs	373	27-Jun	yes
Lookout Mountain	226	11-Jul	yes
Lookout Mountain	231	11-Jul	--
Lookout Mountain	234	11-Jul	yes
Lookout Mountain	240	11-Jul	--
Lookout Mountain	241	11-Jul	yes
Lookout Mountain	242	11-Jul	yes
Lookout Mountain	244	11-Jul	yes
Lookout Mountain	247	11-Jul	yes
Lookout Mountain	248	11-Jul	yes
Lookout Mountain	252	11-Jul	yes
Lookout Mountain	261	11-Jul	yes
Lookout Mountain	262	11-Jul	--
Lookout Mountain	272	11-Jul	--
Lookout Mountain	280	11-Jul	--
Lookout Mountain	293	11-Jul	yes
Lookout Mountain	301	11-Jul	yes
Lookout Mountain	308	11-Jul	yes
Lookout Mountain	310	11-Jul	--

Lookout Mountain	311	11-Jul	--
Lookout Mountain	316	11-Jul	--
Lookout Mountain	319	11-Jul	yes
Lookout Mountain	335	11-Jul	--
Lookout Mountain	355	11-Jul	yes
Lookout Mountain	362	11-Jul	--
Lookout Mountain	368	11-Jul	yes
Lookout Mountain	375	11-Jul	yes
Ski Apache base	232	25-Jul	yes
Ski Apache base	235	25-Jul	--
Ski Apache base	250	25-Jul	yes
Ski Apache base	255	25-Jul	--
Ski Apache base	256	25-Jul	yes
Ski Apache base	265	25-Jul	yes
Ski Apache base	275	25-Jul	--
Ski Apache base	278	25-Jul	yes
Ski Apache base	279	25-Jul	--
Ski Apache base	283	25-Jul	--
Ski Apache base	288	25-Jul	yes
Ski Apache base	291	25-Jul	yes
Ski Apache base	296	25-Jul	yes
Ski Apache base	299	25-Jul	--
Ski Apache base	318	25-Jul	yes
Ski Apache base	320	25-Jul	yes
Ski Apache base	328	25-Jul	--
Ski Apache base	352	25-Jul	--
Ski Apache base	366	25-Jul	--
Ski Run Road	227	28-Jul	--
Ski Run Road	229	28-Jul	yes
Ski Run Road	270	28-Jul	--
Ski Run Road	271	28-Jul	yes
Ski Run Road	281	28-Jul	yes
Ski Run Road	282	28-Jul	--
Ski Run Road	284	28-Jul	yes
Ski Run Road	298	28-Jul	yes
Ski Run Road	300	28-Jul	yes
Trail 25 between Monjeau and Buck	313	28-Jul	yes
Trail 25 between Monjeau and Buck	324	28-Jul	--
Trail 25 between Monjeau and Buck	325	28-Jul	--
Trail 25 between Monjeau and Buck	327	28-Jul	--
Trail 25 between Monjeau and Buck	330	28-Jul	--

Trail 25 between Monjeau and Buck	347	28-Jul	--
Trail 25 between Monjeau and Buck	353	28-Jul	--
Trail 25 between Monjeau and Buck	357	28-Jul	yes
Trail 25 between Monjeau and Buck	358	28-Jul	--
Trail 25 between Monjeau and Buck	359	28-Jul	yes
Trail 25 between Monjeau and Buck	360	28-Jul	--
Trail 25 between Monjeau and Buck	363	28-Jul	--
Trail 25 between Monjeau and Buck	365	28-Jul	--

Table 20. Sites sampled between 8 August and 27 September as part of the core sampling areas.

Descriptive Location	Unique site ID	Date of first survey	Chipmunk detected on camera
Lookout Mountain Core	400	8-Aug	yes
Lookout Mountain Core	401	8-Aug	--
Lookout Mountain Core	416	8-Aug	--
Lookout Mountain Core	417	8-Aug	yes
Lookout Mountain Core	422	8-Aug	yes
Lookout Mountain Core	423	8-Aug	yes
Lookout Mountain Core	424	8-Aug	--
Lookout Mountain Core	428	8-Aug	--
Lookout Mountain Core	429	8-Aug	yes
Lookout Mountain Core	441	8-Aug	--
Lookout Mountain Core	445	8-Aug	--
Lookout Mountain Core	446	8-Aug	--
Lookout Mountain Core	448	8-Aug	--
Lookout Mountain Core	451	8-Aug	--
Lookout Mountain Core	455	8-Aug	--
Lookout Mountain Core	456	8-Aug	yes
Lookout Mountain Core	458	8-Aug	--
Lookout Mountain Core	459	8-Aug	yes
Lookout Mountain Core	462	8-Aug	yes
Lookout Mountain Core	466	8-Aug	yes
Lookout Mountain Core	467	8-Aug	yes
Lookout Mountain Core	469	8-Aug	yes
Lookout Mountain Core	482	8-Aug	yes
Lookout Mountain Core	484	8-Aug	yes
Lookout Mountain Core	489	8-Aug	yes
Lookout Mountain Core	404	12-Aug	yes
Lookout Mountain Core	405	12-Aug	yes
Lookout Mountain Core	406	12-Aug	--
Lookout Mountain Core	407	12-Aug	--

Lookout Mountain Core	408	12-Aug	--
Lookout Mountain Core	409	12-Aug	yes
Lookout Mountain Core	412	12-Aug	--
Lookout Mountain Core	415	12-Aug	yes
Lookout Mountain Core	418	12-Aug	yes
Lookout Mountain Core	420	12-Aug	yes
Lookout Mountain Core	426	12-Aug	--
Lookout Mountain Core	427	12-Aug	yes
Lookout Mountain Core	434	12-Aug	yes
Lookout Mountain Core	436	12-Aug	--
Lookout Mountain Core	440	12-Aug	yes
Lookout Mountain Core	442	12-Aug	yes
Lookout Mountain Core	444	12-Aug	--
Lookout Mountain Core	453	12-Aug	yes
Lookout Mountain Core	463	12-Aug	yes
Lookout Mountain Core	468	12-Aug	yes
Lookout Mountain Core	471	12-Aug	--
Lookout Mountain Core	487	12-Aug	yes
Lookout Mountain Core	491	12-Aug	yes
Lookout Mountain Core	492	12-Aug	yes
Lookout Mountain Core	493	12-Aug	yes
Nogal Peak Core	495	24-Aug	yes
Nogal Peak Core	502	24-Aug	--
Nogal Peak Core	507	24-Aug	yes
Nogal Peak Core	508	24-Aug	--
Nogal Peak Core	510	24-Aug	--
Nogal Peak Core	513	24-Aug	--
Nogal Peak Core	514	24-Aug	--
Nogal Peak Core	518	24-Aug	--
Nogal Peak Core	519	24-Aug	yes
Nogal Peak Core	523	24-Aug	--
Nogal Peak Core	532	24-Aug	--
Nogal Peak Core	539	24-Aug	--
Nogal Peak Core	543	24-Aug	--
Nogal Peak Core	544	24-Aug	yes
Nogal Peak Core	545	24-Aug	yes
Nogal Peak Core	548	24-Aug	--
Nogal Peak Core	555	24-Aug	--
Nogal Peak Core	557	24-Aug	yes
Nogal Peak Core	558	24-Aug	--
Nogal Peak Core	564	24-Aug	--

Nogal Peak Core	568	24-Aug	--
Nogal Peak Core	572	24-Aug	--
Nogal Peak Core	575	24-Aug	--
Nogal Peak Core	583	24-Aug	--
Nogal Peak Core	588	24-Aug	yes
Nogal Peak Core	589	24-Aug	--
Nogal Peak Core	590	24-Aug	--
Nogal Peak Core	501	30-Aug	--
Nogal Peak Core	515	30-Aug	--
Nogal Peak Core	525	30-Aug	--
Nogal Peak Core	546	30-Aug	--
Nogal Peak Core	559	30-Aug	--
Nogal Peak Core	585	30-Aug	--
Nogal Peak Core	586	30-Aug	yes
Nogal Peak Core	591	30-Aug	--
Nogal Peak Core	592	30-Aug	yes
Nogal Peak Core	498	24-Aug	--
Nogal Peak Core	556	24-Aug	--
Nogal Peak Core	531	30-Aug	--
Nogal Peak Core	571	30-Aug	--
Monjeau Peak Core	595	21-Sep	--
Monjeau Peak Core	599	21-Sep	yes
Monjeau Peak Core	605	21-Sep	yes
Monjeau Peak Core	607	21-Sep	--
Monjeau Peak Core	609	21-Sep	--
Monjeau Peak Core	611	21-Sep	yes
Monjeau Peak Core	617	21-Sep	yes
Monjeau Peak Core	618	21-Sep	yes
Monjeau Peak Core	623	21-Sep	yes
Monjeau Peak Core	626	21-Sep	--
Monjeau Peak Core	630	21-Sep	--
Monjeau Peak Core	642	21-Sep	yes
Monjeau Peak Core	648	21-Sep	--
Monjeau Peak Core	650	21-Sep	--
Monjeau Peak Core	652	21-Sep	yes
Monjeau Peak Core	653	21-Sep	yes
Monjeau Peak Core	655	21-Sep	--
Monjeau Peak Core	657	21-Sep	yes
Monjeau Peak Core	658	21-Sep	yes
Monjeau Peak Core	662	21-Sep	yes
Monjeau Peak Core	665	21-Sep	--

Monjeau Peak Core	669	21-Sep	--
Monjeau Peak Core	670	21-Sep	--
Monjeau Peak Core	671	21-Sep	--
Monjeau Peak Core	614	27-Sep	yes

VIII. Supplemental Material: Chipmunk Identification Training

Chipmunk Identification Training

Fiona McKibben and Jennifer Frey

The chipmunk identification training documents are proprietary material developed by Fiona McKibben and Jennifer Frey of New Mexico State University as part of their research on *Neotamias minimus atristriatus*. These materials may not be shared or adapted for any use without explicit written permission from Dr. Frey.

General instructions:

1) Copy the Microsoft Excel Workbook titled “data sheet” and rename ending with your three letter initials (for example: data sheet FEM). Open this file and fill in your full name and the date in the tab labeled “Part 1”.
2) Carefully read the coding instructions and definitions below. Study the “photo comparisons” for examples.
3) Open the PDF document titled “Part 1 – pre test”. Complete the Part 1 tab in the data sheet. There are 20 slides in this pre test. In Part 1 code the species and confidence. You do not need to code all seventeen pelage traits.
4) Repeat steps 1-3 for Part 2. In this section you will need to code all seventeen pelage traits for each individual slide. There are 504 slides in the Part 2 (nonant) training set.
5) After completing Part 2 you may open the PDF titled “answer key Part 2” and compare your answers to the correct answers. Feel free to study the images and assess which traits led to mistakes. DO NOT edit your data sheet. This data sheet will be used for analysis.
6) Repeat steps 1-5 for Part 3 and Part 4. There are 168 slides and 56 slides respectively.

Coding instructions:

1. Study the definitions and the photo comparisons below to familiarize yourself with the two species.
2. For each slide in the powerpoint, code the seventeen pelage traits. Enter "0" if you cannot see the feature or you are unsure. Enter "1" if the feature appears to match the *N. minimus atristriatus* description. Enter "2" if the feature appears to match the *N. canipes* description.
3. In the "N. m. atristriatus or N. canipes column", code "1" if you think it is *N. m. atristriatus* or "2" if you think it is *N. canipes*
4. In the "confidence" column you will assign a confidence rank for how confident you are in the final assignment of species (not referring to individual characteristics). Confidence ranks are as follows: very confident (4), somewhat confident (3), not very confident (2), no confidence (1)

Distinguishing features in qualitative pelage traits between *N. minimus* and *N. canipes*		
Pelage trait	***N. minimus atristriatus***	***N. canipes***
post auricular patches: small patches of lighter fur directly posterior to ears	small and darker	larger, prominent and white
lower face: lighter patch below lowest dark stripe	dingy or yellowish	whitish or clean pale grey
lower light face stripe: light stripe below eye that goes to ear	greyish or dingy	white
upper light face stripe: light stripe/patch above eye	less white, less prominent	white
crown: top of head	yellowish, orange, darker	less orange, lighter
shoulder	yellowish, orange, darker, more intense	greyer, lighter, less intense
dark outer stripes: there are five dark dorsal stripes - this refers to the pair of outer most stripes, these stripes may be indistinct	Blacker; narrower and more distinct (looks like it was drawn on with a marker)	Browner; wider and less distinct (looks like it was painted on with a brush)
white outer stripes: there are four light stripes - this refers to the pair of outer most light stripes	dingy mixed with brown hairs	white
dark median stripes: the pair of dark stripes immediately lateral to the middle dark stripe	darker, thin, blackish (looks like it was drawn on with a marker)	thick, brownish (looks like it was painted on with a brush)
dark stripes on rump: this character describes whether the pair of dark median stripes changes color over the rump	the pair of dark median stripes remains dark and distinct all the way down over the rump to near the base of the tail	the pair of dark median stripes changes color posteriorly, becoming a lighter brown and may become so indistinct as to disappear
hip	yellower/oranger	grey
dorsal hindfoot	pale yellowish orange	yellowish grey
dorsal tail	hairs mixed black and orange	hairs mixed black and white
ventral tail	orange down the center, black edges, orange tipped hairs	orange down the center, black edges, white tipped hairs
belly	light beige, yellowish or orange; darker	Creamy or white or grey; lighter; may have an orange tint
underside of back leg	more orange	white/grey, may have an orange tint
underside of front leg	orange	white/grey

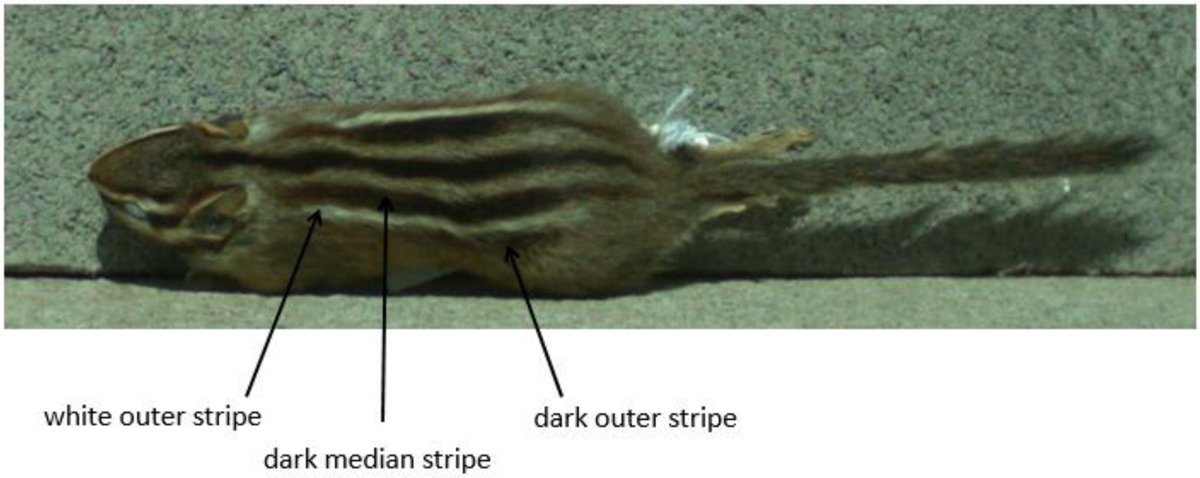
Photo Comparisons

Comparison of general features; five *N. m. atristriatus* on the left, five *N. canipes* on the right.

Comparison of belly pelage; five *N. m. atristriatus* on the left, five *N. canipes* on the right

Close up comparison of belly pelage; two *N. m. atristriatus* on left, two *N. canipes* on right

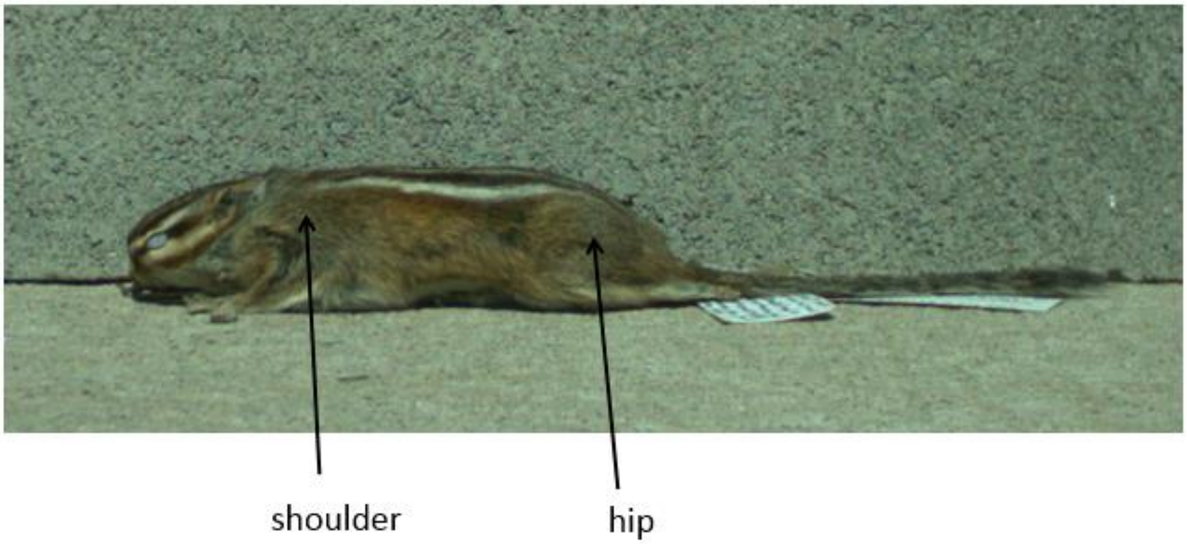
Locations of dorsal stripes



Comparison of stripes on rump; *N. m. atristriatus* on left, *N. canipes* on right

Comparison of hindfoot color; two *N. m. atristriatus* on the right, two *N. canipes* on the left

Locations of shoulder and hip



Comparison of post auricular patches; *N. m. atristriatus* on left, *N. canipes* on right

Comparison of face coloring; two *N. m. atristriatus* above, two *N. canipes* below