Post-wildfire Habitat Use by the Peñasco Least Chipmunk, 2022-2024

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South face of Nogal Peak in the Lincoln National Forest, December 2022

(Photo: William Grooms)

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Multiscale Habitat Selection to Investigate Competition as a Threat to the Peñasco Least Chipmunk (*Neotamias minimus atristriatus*)

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Introduction

The Peñasco least chipmunk (*Neotamias minimus atristriatus*) is endemic to the Sacramento Mountains in southern New Mexico, USA (Bailey, 1931; Conley, 1970; Sullivan, 1985; Sullivan & Petersen, 1988). The Peñasco least chipmunk is extirpated from much of its historical range (Frey & Boykin, 2007; Frey & Hays, 2017; Hope & Frey, 2000) and consequently is listed as endangered by the state of New Mexico (NMDGF 2016) and as endangered with designated critical habitat by the USFWS (U.S. Fish and Wildlife Service, 2024). The taxon is only known to persist in two populations occurring on Lookout Mountain and Nogal Peak in the northern Sierra Blanca subrange (McKibben & Frey, 2025).

The Lookout Mountain population occurs in subalpine coniferous forest dominated by old-growth Engelmann spruce (*Picea engelmannii*) interspersed with subalpine meadows and an understory of gooseberry currant shrubs (*Ribes montigenum*). Lookout Mountain is the largest remaining patch of this vegetation type on public lands in the Sacramento Mountains. Formerly, similar Engelmann spruce forests were likely widespread across the upper elevations of the Sierra Blanca subrange. Recent research estimates that the Lookout Mountain population of Peñasco least chipmunks is comprised of approximately 44 individuals, occupying approximately 15 hectares of habitat (McKibben et al., 2021; McKibben & Frey, 2025).

The habitat occupied by Peñasco least chipmunks at Nogal Peak is a Gambel oak (*Quercus gambelii*) shrubland, characterized by dense shrubs interspersed with occasional conifer trees and patches of grass. The shrub form of Gambel oak is a common successional species following disturbance in coniferous forests (especially wildfire), and Nogal Peak likely represents an example of this process. The presence of Peñasco least chipmunks in the Gambel oak disclimax vegetation community on Nogal Peak is important because it suggests that these chipmunks may have the behavioral plasticity necessary to persist in other wildfire-transformed vegetation communities across their range. For the purposes of our study, we refer to these two populations and the intervening high-elevation areas of the subrange as the Peñasco least chipmunk's contemporary range.

The persistence of the Peñasco least chipmunk is threatened by habitat alteration, drought, wildfire, and potential competition with the gray-footed chipmunk (*N.canipes*; New Mexico Department of Game and Fish, 2016; U.S. Fish and Wildlife Service, 2024). The gray-footed chipmunk is a larger and more arboreal species that is a habitat generalist within coniferous forests (Best et al., 1992). When sympatric with other chipmunk species, least chipmunks are often displaced by larger and more aggressive congeners (Chappell, 1978; Poffenroth & Matson, 2007; Root et al., 2001), lending support to the hypothesis that interspecies competition with the gray-footed chipmunk is contributing to the decline of Peñasco least chipmunks in this system.

The potential for competition exists when two species share the use of resources that are limited in their environment. Interspecies competition can take the form of exploitative interactions (i.e., one species consumes the shared resource, making it unavailable to the other species) or interference interactions (i.e., one species restricts access to the shared resource through territorial or aggressive behaviors). Proving that competition is the underlying mechanism driving species distribution is difficult in the absence of manipulative experiments, but we propose a framework where a comparison of habitat selection at different scales will identify any overlap of habitat preferences between the chipmunk species. This overlap highlights the shared resources and thus may be the most likely source of any ongoing competition between the species. If no overlap exists, then the species might have co-evolved to avoid competition altogether or there could be intense competition resulting in complete exclusion of the inferior competitor. Our approach will not distinguish between these extreme possibilities; however, if the habitat preference of one species varies depending on the presence or absence of the other species, then we will have identified a shared resource where competition between the chipmunk species is likely to have a negative impact on the persistence of Peñasco least chipmunks.

The goal of this study was to compare habitat selection by the Peñasco least chipmunk and the gray-footed chipmunk at the landscape and microhabitat scales to identify which resources the species are sharing within the contemporary Peñasco least chipmunk range (Manly et al., 2002). At the landscape scale, we evaluated gray-footed chipmunk habitat selection in a series of three single-species occupancy models. We explicitly tested the hypothesis that the presence of gray-footed chipmunks limits occupancy by Peñasco least chipmunks using a multi-species occupancy model (MacKenzie et al., 2018). We described use of microhabitats by both species at Nogal Peak using five principal component analyses. We conducted a formal evaluation of microhabitat selection by both species at Nogal Peak following a use-versus-availability design using logistic regression models. In addition, we tested the ability to reliably identify and distinguish between the two chipmunk species by using morphological characteristics measured in remote camera photos.

Methods

Study Area

The Sacramento Mountains is an isolated mountain range located in southern New Mexico (NM), USA. The mountain range runs in a general north-to-south direction and consists of two distinct subranges: the South Sacramento Mountains in the south and Sierra Blanca in the north. Our study area is located within the Sierra Blanca subrange, primarily in the White Mountain Wilderness Area of the Lincoln National Forest, Lincoln County, NM (Figure 1).

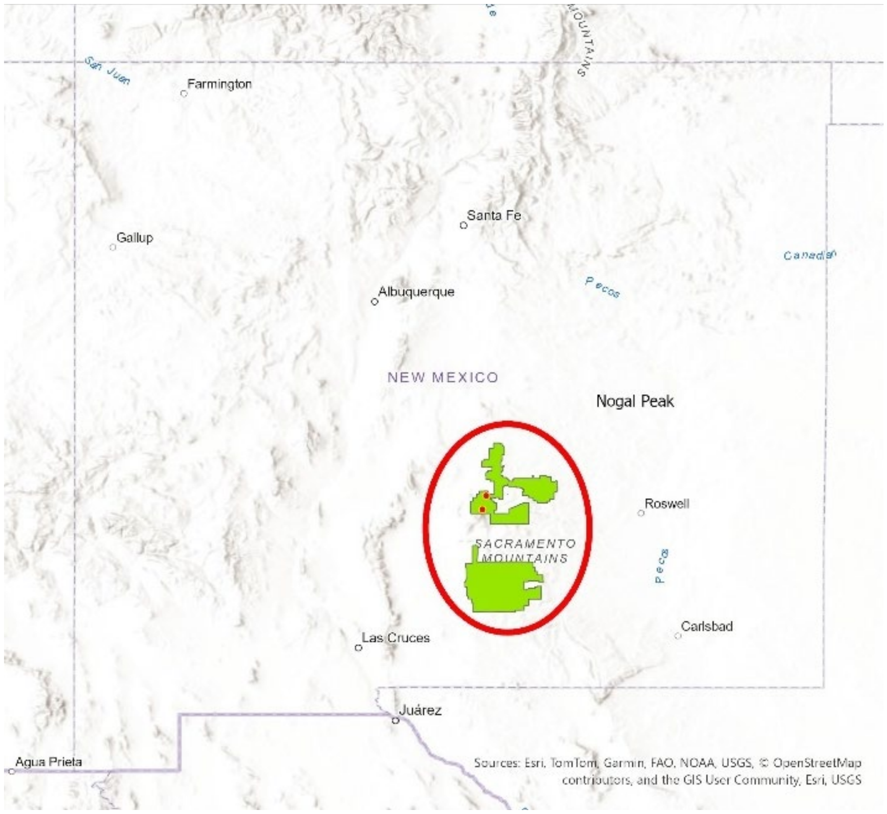

Figure 1. Location of study area for analysis of landscape and microhabitat scale habitat selection by the Peñasco least chipmunk (*Neotamias minimus atristriatus*) and gray-footed chipmunk (*N. canipes*) in the Sierra Blanca subrange of the Sacramento Mountains, NM, USA, 2018-2023.

Our landscape-scale analysis was limited to areas above 2,500 m elevation in the Sierra Blanca subrange of the Sacramento Mountains. Isolated areas of alpine tundra and subalpine grasslands can be found on the highest summits above timberline (> 3,500 m; Dick-Peddie, 1993). Below timberline (~ 2,980-3,660 m), subalpine coniferous forests are dominated by Engelmann spruce (*Picea engelmannii*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*). Subalpine grasslands and meadows dominated by Thurber's fescue (*Festuca thurberi*) are found on high ridges and in natural openings within the subalpine forest, respectively (Moir, 1967). The boundary between subalpine and montane coniferous forest varies based on location, slope, and soil conditions, but on Sierra Blanca the transition between forest types occurs at about 2,980 m elevation (Dye & Moir, 1977). Below the subalpine forest, mixed conifer forests of predominately Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*) are found on cooler aspects. Ponderosa pine (*Pinus ponderosa* var. *scopulorum*) forests with Gambel oak (*Quercus gambelii*) and New Mexico locust (*Robinia neomexicana*) occurs at lower elevations than mixed conifer forest and on warmer aspects. Meadows are interspersed throughout these forests. Forbs share dominance with grasses in these meadows (Dick-Peddie, 1993) and forbs from the *Lupinus*, *Lathyrus*, *Penstemon*, *Senecio*, *Solidago*, and *Astragalus* genera are abundant (Alexander et al., 1984). Very limited amounts of the *Picea engelmannii/Ribes montigenum* (PIEN/RIMO; United States Department of Agriculture, Forest Service, 1997) plant association are contained within the study area. The PIEN/RIMO association is only known to exist on Lookout Mountain and in the Ice Springs area and is characterized by nearly pure stands of large-diameter Engelmann spruce trees with an understory of gooseberry currant (*Ribes* *montigenum*). The PIEN/RIMO plant association is closely associated with the contemporary Peñasco least chipmunk distribution (McKibben & Frey, 2025).

Our microhabitat study was conducted on Nogal Peak (~2,967 m maximum elevation). Nogal Peak is a prominent peak in the northern portion of the Sierra Blanca subrange, approximately 10 km north of Lookout Peak. Our study was limited to the area on Nogal Peak above the Crest #25 and Tortolita Canyon #54 trails on the south and west sides and above the 2,750 m contour on the north and east sides. In this area, the boundary between subalpine and montane coniferous forests is indistinct. The area appears to be in a prolonged mid-successional seral stage (Dick-Peddie 1993) and there are few mature conifer trees present. When present, Douglas fir, white fir, ponderosa pine, twoneedle pinyon (*Pinus edulis*), quaking aspen (*Populus tremuloides*), and velvet ash (*Fraxinus velutina*) are found individually or in small patches. Numerous forbs and perennial bunchgrass species occur across the study area, including *Aster* spp., *Lupine* spp., *Achillea* spp., Fendler's meadowrue (*Thalictrum fendleri*), and mountain nettle (*Urtica gracilenta*). The southern aspect of Nogal Peak is dominated by thick patches of Gambel oak in shrub form intermixed with *Ribes* spp. and *Artemisia* spp. On the northern aspect, Gambel oak in tree form occurs in large patches, creating a canopy with herbaceous and low-growing shrub cover below. Patches of Gambel oak shrubs, New Mexico locust, rockspirea (*Holodiscus dumosus*), and currants (*Ribes cereum*, *R. pinetorum*, *R. montigenum*, *R. wolfii*) were distributed between stands of Gambel oak (Alexander et al., 1984). Mountain nettle was present in greater abundance inside of the active grazing allotment on the north side of Nogal Peak (personal observation).

Landscape-Scale Analyses

Overview of Landscape-Scale Analyses

We evaluated chipmunk habitat selection at the landscape scale using occupancy models (MacKenzie et al., 2018). We utilized an existing dataset that was previously analyzed to investigate landscape-scale habitat selection by the Peñasco least chipmunk (McKibben & Frey, 2025). These data consisted of camera surveys along with field-collected and GIS variables describing site and survey specific characteristics. Motion-activated cameras were deployed at 238 sites for at least 3 days, a time frame adequate to achieve 90% probability detecting at least one chipmunk during the survey period given that the site was occupied (McKibben & Frey, 2025). Because we used the same camera data and variables in our gray-footed chipmunk models, our results are directly comparable to the occupancy model for the Peñasco least chipmunk (McKibben & Frey, 2025).

We evaluated gray-footed chipmunk habitat selection in a series of single-species occupancy models (Table 1). First, we constructed a gray-footed chipmunk detection model (GFC DM) to be used in the remainder of our models. Using that detection model, we modeled gray-footed chipmunk occupancy using three variables from McKibben and Frey (2025) known to influence Peñasco least chipmunk occupancy (GFC SSOM3) to determine if any of the habitat features important to the Peñasco least chipmunk were also important to the gray-footed chipmunk. Next, we modeled gray-footed chipmunk occupancy using a suite of 14 variables predicted to influence occupancy of Peñasco least chipmunks (GFC SSOM14) to understand how the species may be partitioning the environment to avoid competition. Finally, we constructed a gray-footed chipmunk occupancy model (GFC SSOM) using a set of five variables predicted to explicitly influence gray-footed chipmunk habitat selection at the landscape scale.

We tested the hypothesis that gray-footed chipmunks influence the occupancy of Peñasco least chipmunks using a multispecies occupancy model (Table 1). We constructed our multi-species model (MSOM) using the variables from the top single-species occupancy models for each chipmunk species. To improve convergence in our models we checked variables for multicollinearity and did not include any variables with VIF > 10 in our models (Dormann et al., 2013). To further improve convergence, we reduced the complexity of our multispecies model by first conducting univariate tests on the suite of top variables and retained only those variables that performed better than the null model.

We followed an information theoretical approach (Anderson et al., 2000), using exploratory analyses, literature, and personal knowledge to develop *a priori* model sets. Each *a priori* model represented a separate hypothesis that might explain the species' landscape-scale habitat selection. To avoid over-parameterization, we limited our models to one parameter for every ten used sites (Pavlou et al., 2015). Prior to including variables in models, we checked the data for normality and for correlations. We did not include any highly correlated variables ($r \geq |0.7|$) in the same model. We selected top models according to the recommendations in Burnham and Anderson (2002) by assessing relative model fit using AIC corrected for small sample sizes (AICc). All models within Δ2 AICc were considered competitive, and all competitive models were evaluated for uninformative parameters following the methods described in Leroux (2019). Models containing uninformative parameters were removed from further consideration (Arnold, 2010). We averaged across all competitive models and reported the averaged result as the top model (Burnham & Anderson, 2002). All analyses were performed using the "unmarked" (Fiske & Chandler, 2011) and "muMIn" (Bartoń, 2025) packages in program R.

Table 1. List of analyses by scale with names and descriptions of each analysis evaluating multi-scale habitat selection of Peñasco least chipmunk (*Neotamias minimus atristriatus*, PLC) and gray-footed chipmunks (*N. canipes*, GFC) in the contemporary PLC, Sierra Blanca subrange, Sacramento Mountains, NM, 2018-2023.

Name	Description
Landscape-scale analyses	
GFC DM	Gray-footed chipmunk detection
GFC SSOM3	Gray-footed chipmunk occupancy using 3 known PLC occupancy variables
GFC SSOM14	Gray-footed chipmunk occupancy using 14 predicted PLC occupancy variables
GFC SSOM	Gray-footed chipmunk landscape- scale habitat selection model using 5 predicted GFC occupancy variables
MSOM	Multispecies occupancy model
Microhabitat-scale analyses	
PLC PCA1	PCA of microhabitat used by Peñasco least chipmunks (used vs. not used vs. not surveyed sites)
PLC PCA2	PCA of microhabitat used by Peñasco least chipmunks (used vs. random)
PLC REG	Logistic regression of microhabitat selection by Peñasco least chipmunks (used vs. available)
GFC PCA1	PCA of microhabitat used by gray-footed chipmunks (used vs. not used vs. not surveyed sites)
GFC PCA2	PCA of microhabitat used by gray-footed chipmunks (used vs. random)
GFC REG	Logistic regression of microhabitat selection by gray-footed chipmunks (used vs. available)
PLC-GFC PCA	PCA comparing microhabitat used by both species (PLC used vs. GFC used)
PLC-GFC REG	Logistic regression comparing microhabitat used by both species (PLC used vs. GFC used)

Gray-footed Chipmunk Single-Species Occupancy Models

To construct the gray-footed chipmunk single-species occupancy models, we used the data from the first six camera survey days at a site. The prolonged number of survey days improved detection probability during warm weather. Our single-species models therefore included 238 sites surveyed for up to six days, resulting in a total of 1,184 trap days.

GFC DM: Gray-footed chipmunk detection. Failure to adequately account for imperfect detection in occupancy modeling can lead to biased results (MacKenzie et al., 2002), so we evaluated a set of six variables (Table 2) predicted to influence the detection of gray-footed chipmunks. We created a set of 64 *a priori* detection models (Table S1), allowing the probability of detection to vary while holding the probability of occupancy constant. The results of this analysis were used as the detection model for subsequent gray-footed chipmunk occupancy models.

GFC SSOM3: Gray-footed chipmunk occupancy using known Peñasco least chipmunk variables. We modeled the effect of three variables (McKibben & Frey, 2025) known to influence occupancy of Peñasco least chipmunks in this system (Table 3) on gray-footed chipmunk occupancy. We compared the relative strength of this model with a null occupancy model using AICc.

GFC SSOM14: Gray-footed chipmunk occupancy model with predicted Peñasco least chipmunk variables. We modeled the effect of 14 variables predicted to influence Peñasco least chipmunk occupancy (Table 3) on the gray-footed chipmunk. We used the *a priori* model structure described in McKibben and Frey (2025).

GFC SSOM: Gray-footed chipmunk landscape-scale habitat selection model. We modeled the effect of five variables (Table 4) predicted to influence occupancy of gray-footed chipmunks in a set of 32 *a priori* models (Table S2).

Table 2. Variable names and descriptions used to model gray-footed chipmunk (GFC) detection probability in the contemporary Peñasco least chipmunk range (model GFC DM), Sierra Blanca subrange, 2019. Variables were field-collected along three 20-m transects unless otherwise indicated.

Variable	Description
Scent lure age	Days since scent lure deployment
Precipitation	Categorical indicating whether it rained on a survey date, recorded at Sierra Blanca weather station
Max. daily temp	Maximum temperature at site on survey date recorded on iButton
Survey period	Categorical indicating which period the survey was conducted in (McKibben and Frey 2025)
Rock cover	Sum of mean amount of rock, boulder, and bedrock cover on transects
Canopy cover	Canopy cover at survey location measured on spherical densitometer

Table 3. Variable names and descriptions used to model gray-footed chipmunk (GFC) occupancy in the contemporary Peñasco least chipmunk (PLC) range (models GFC SSOM3 and GFC SSOM14), Sierra Blanca subrange, 2019. Variables were previously used to model occupancy of PLC at the same survey sites (McKibben & Frey, 2025). Variables were collected in the field along three 20-m transects unless otherwise indicated as collected or derived via Geographic Information Systems (GIS).

Model	Variable	Description
Detection	Max. daily temperature	Maximum temperature at site on survey date recorded on iButton
	Rock cover	Sum of mean amount of rock, boulder, and bedrock cover on transects
	Canopy cover	Canopy cover at survey location measured on spherical densitometer
GFC occupancy model using 3 known PLC variables	Elevation	Mean elevation at site (GIS; 10 m resolution)
	Visual obstruction	Mean percent visual obstruction below 1 m at site
	Small-scale edge	Interaction between tree count on belt transects and mean percent herbaceous cover
GFC occupancy model using 14 hypothesized PLC variables	Community	Categorical with five community types: dead, montane, corkbark fir dominant, and open
	Montane	Categorical indicating presence/absence in montane coniferous forest
	Corkbark fir dominant	Categorical indicating presence/absence in corkbark fir dominant forest
	Engelmann spruce dominant	Categorical indicating presence/absence in Engelmann spruce dominant forest
	Open	Categorical indicating presence/absence in area with no trees
	Elevation	Mean elevation at site (GIS; 10 m resolution)
	Dead tree count	Count of dead trees along belt transects
	Ecotone	Categorical indicating presence/absence in 80 m wide ecotone between contiguous coniferous and contiguous herbaceous cover (GIS)
	Subalpine edge	Interaction between subalpine cover and herbaceous cover in 80 m radius (GIS)
	Small-scale edge	Interaction between tree count on belt transects and mean percent herbaceous cover
	Visual obstruction	Mean percent visual obstruction below 1 m at site
	Shrub cover	Mean percent shrub cover
	Herbaceous cover	Mean percent herbaceous cover
	Mixed understory cover	Interaction between mean percent herbaceous cover and shrub cover

Table 4. Variable names and descriptions used to model gray-footed chipmunk (GFC) occupancy in the contemporary Peñasco least chipmunk range (model GFC SSOM), Sierra Blanca subrange, 2019. Variables created and previously used to model occupancy probabilities of Peñasco least chipmunk in the same area (McKibben & Frey, 2025). Variables were field collected along three 20 m transects unless otherwise indicated.

Submodel	Variable	Description
Detection	Max. daily temperature	Maximum temperature at site on survey date recorded on iButton
	Rock cover	Sum of mean amount of rock, boulder, and bedrock cover on transects
	Canopy cover	Canopy cover at survey location measured on spherical densitometer
Occupancy	Herbaceous cover	Mean percent forb and grass cover
	Engelmann spruce dominant	Categorical indicating presence/absence in Engelmann spruce dominant forest
	Boulder height	Height of tallest boulder within 10 m of site
	Montane shrub cover	Quadratic response to montane shrub cover on transects
	Gooseberry currant cover	Mean percent of *Ribes montigenum*

Peñasco Least Chipmunk and Gray-footed Chipmunk Multi-species Occupancy Model

We constructed a multi-species occupancy model (MSOM) using the suite of variables in the top occupancy models for gray-footed chipmunks based on results herein, and for Peñasco least chipmunks from McKibben and Frey (2025; Table 5). Our multi-species model explicitly addresses the question of whether occupancy by the Peñasco least chipmunk is limited by the presence of gray-footed chipmunks by conditioning the Peñasco least chipmunk's occupancy on whether gray-footed chipmunks are at the site (Rota et al., 2016). Based on the likelihood that Peñasco least chipmunks are the subordinate species in the interaction, our multi-species model only conditioned Peñasco least chipmunk occupancy by the occupancy state of gray-footed chipmunks, and not vice-versa. Any variable with a higher probability of Peñasco least chipmunk occupancy in the absence of gray-footed chipmunks highlights a potential source of competition between chipmunks.

We used the same camera survey results in this multi-species model as in our single-species models; however, at some sites the cameras failed and did not collect data for the duration of their deployment. To improve the convergence of our model, we removed any site with missing data by truncating the data to the first four survey days, which eliminated 7 sites. Our multi-species model therefore included 231 sites surveyed for 4 days, for a total of 924 trap days. To avoid over-parameterization in our models, we used AICc to rank the relative strength of variables in our gray-footed chipmunk detection model (GFC DM) and selected only the strongest variable to be included in our multi-species model (Table S3). We took the same approach to select the strongest detection variable for Peñasco least chipmunks (McKibben & Frey, 2025). We combined these variables with the top occupancy variables for each chipmunk species to create 120 *a priori* multi-species models (Table S4).

Table 5. Variable names and descriptions used to model Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) multispecies occupancy in the contemporary PLC range (model MSOM), Sierra Blanca subrange, 2019. Variables were created and previously used to model occupancy probabilities of PLC in the same area (McKibben & Frey, 2025). Variables were field collected along three 20-m transects unless otherwise indicated.

Submodel	Species	Variable	Description
Detection	GFC	Rock cover	Sum of mean amount of rock, boulder, and bedrock cover on transects
		Canopy cover	Canopy cover at survey location measured on spherical densitometer
	PLC	Max. daily temperature	Maximum temperature at site on survey date recorded on iButton
		Precipitation	Categorical indicating whether it rained on a survey date, recorded at Sierra Blanca weather station
Occupancy	GFC	Herbaceous cover	Mean percent herbaceous cover
		Boulder height	Height of tallest boulder within 10 m of site
		Montane shrub cover	Quad. response to montane shrub cover on transects
		Small-scale edge	Interaction between tree count on belt transects and mean percent herbaceous cover
	PLC	Elevation	Mean elevation at site (GIS; 10 m resolution)
		Visual obstruction	Mean percent visual obstruction below 1 m at site
		Herbaceous cover	Mean percent herbaceous cover
		Boulder height	Height of tallest boulder within 10 m of site
		Small-scale edge	Interaction between tree count on belt transects and mean percent herbaceous cover
	Both	Elevation	Mean percent forb and grass cover
		Visual obstruction	Mean percent visual obstruction below 1 m at site
		Small-scale edge	Interaction between tree count on belt transects and mean percent herbaceous cover

Microhabitat-Scale Analyses

We surveyed for Peñasco least chipmunks on Nogal Peak using motion-activated cameras following the methods of McKibben and Frey (2025). Because we anticipated the occurrence of Peñasco least chipmunks on Nogal Peak to be low, our main concern was obtaining an adequate number of detections for analysis. Our initial survey effort was concentrated near historical Peñasco least chipmunk detections. We selected sites that maximized the likelihood of detection where visual obstruction was high along the edges between shrubs and grass in the vicinity of large-diameter trees (McKibben & Frey, 2025). We considered a site to be “used” if at least one Peñasco least chipmunk was detected. A paired random site was generated from used sites following the procedures outlined in McKibben and Frey (2025). Any randomly generated point falling outside of the study area boundaries or in terrain deemed unsafe for us to survey due to dangerous topography was rejected and regenerated. Variable data was collected at all used and random sites following the methods for the within-home-range-scale habitat selection of McKibben and Frey (2025). We also collected variable data at non-detection sites opportunistically to increase our sample size. Photographs of chipmunks were identified following the methods of McKibben and Frey (2021). All photos identified as Peñasco least chipmunks by our trained observers were subject to review by J. Frey, F. McKibben, and W. Grooms to confirm the identification to ensure that only unambiguous identifications were counted as detections in our analyses.

We deployed cameras at 172 sites. Most cameras were left in place for 14 days, but some were left in place long-term near historical detection sites, resulting in a total of 8,643 camera days. We collected habitat data at 6 sites used by Peñasco least chipmunks, 47 sites used by gray-footed chipmunks, 3 sites used by both species, 29 sites randomly generated from used sites, and opportunistically at 9 other sites for a total of 94 habitat surveys.

We used field-collected and GIS variables collected following the methods of McKibben and Frey (2025; Table 6) in a principal components analysis (PCA) to describe the environment on Nogal Peak. This approach allowed us to identify factors that account for observed patterns across multiple variables and to condense that information into a set of smaller, composite variables (McGarigal et al., 2000). We conducted separate PCAs in which we compared sites used by each species with unused sites (surveyed with camera but no detection) or available sites (not surveyed with camera) and paired random sites. To evaluate the potential for competition between the chipmunk species, we compared conditions at sites used by Peñasco least chipmunks with those used by gray-footed chipmunks. Because our PCAs were used strictly for descriptive purposes, we relaxed the strict assumptions of multivariate normality and linear relationships but attempted to adhere to them as much as possible (McGarigal et al., 2000). We followed the rule of thumb that the number of variables should not exceed the number of sampled sites.

We used logistic regression to formally test the patterns suggested by the PCAs. We followed an information theoretic approach (Andersen et al. 2000) to develop *a priori* model sets. To select variables for these models we conducted univariate tests of the variables contained in the PCAs, then retained those variables that performed better than the null. Each *a priori* model represented a separate hypothesis that might explain the species' microhabitat selection on Nogal Peak. We followed the same approach as outlined in the landscape-scale methods to select and evaluate our logistic regression models. All analyses were performed using the "MASS" (Venables & Ripley, 2002) and "FactoMineR" (Lê et al., 2008) packages in program R.

Microhabitat selection by Peñasco least chipmunks on Nogal Peak. We described Peñasco least chipmunk microhabitat use on Nogal Peak with two separate PCAs. The first PCA (PLC PCA1) compared 9 used sites with 56 not used sites and 29 sites that were available but not trapped. For the second PCA (PLC PCA2), we compared the 9 used sites with 9 paired, randomly generated sites. To test the influence that the variables described by our PCAs had on the probability that a site will be used by a Peñasco least chipmunk, we created a set of 32 *a priori* logistic regression models (PLC REG, Table S5) comparing 9 used with 85 available sites.

Microhabitat selection by gray-footed chipmunks on Nogal Peak. We described gray-footed chipmunk microhabitat use on Nogal Peak with two PCAs. The first PCA (GFC PCA1) compared 50 used sites with 15 not used and 29 sites that were available but not trapped. For the second PCA (GFC PCA2), we compared 22 sites used by gray-footed chipmunks with 22 paired, randomly generated sites. To test the influence that the variables described on our PCAs have on the probability that a site will be used by a gray-footed chipmunk, we created a set of 74 *a priori* logistic regression models (GFC REG, Table S6) comparing 50 used sites with 44 available sites.

Comparison of microhabitat selection between Peñasco least chipmunks and gray-footed chipmunks on Nogal Peak. We compared microhabitat use between the two chipmunk species on Nogal Peak with a PCA (PLC-GFC PCA) comparing 9 sites used by Peñasco least chipmunks with 50 sites used by gray-footed chipmunks. To test the comparison of chipmunk microhabitat use described in our PCA, we created a set of 55 *a priori* logistic regression models (PLC-GFC REG, Table S7) comparing sites used by each species.

Table 6. Variable names, descriptions, and analyses used to evaluate microhabitat use and selection by the Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) on Nogal Peak, 2018-2023. Variables were collected in the field along four 10 m transects (belt transect 1 m both sides of transect) unless otherwise indicated. Trees were > 2 m tall, boulders were 0.5 - 5 m in any dimension. "X" indicates that the variable was included in the analysis.

Variable name	Description	PLC PCA1	PLC PCA2	GFC PCA1	GFC PCA2	PLC-GFC PCA
Elevation	Mean elevation at site (GIS; 10 m resolution)	x	x	x	x	x
Slope	Mean slope at site (GIS; 100 m resolution)	x	x	x	x	x
Aspect	Folded aspect at site (GIS; 100 m resolution)	x		x	x	x
bldr.count	Count of boulders on belt transects	x	x	x	x	x
QUGA.big10	Count of *Quercus gambelii* trees > 10 cm diameter at breast height (dbh) on belt transects	x	x	x	x	x
QUGA.small	Count of *Quercus gambelii* trees 5 - 10 cm dbh on belt transects	x		x	x	x
PIPO.count	Count of *Pinus ponderosa* trees > 5 cm dbh on belt transects	x		x	x	x
PIED.count	Count of *Pinus edulis* trees > 5 cm dbh tall on belt transects	x		x	x	x
bldr.hght	Height of tallest boulder within 10 m of site	x		x	x	x
visual.obstr	Mean percent visual obstruction below 1 m at site	x	x	x	x	x
shrub.hght	Height of tallest shrub within 10 m of site	x		x	x	x
shrub.dist	Distance from site to nearest shrub	x	x	x	x	x
tree.dist	Distance from site to nearest tree (> 5 cm dbh)	x	x	x	x	x
rock.cover	Mean percent rock cover (0.1 - 0.5 m) on transects	x	x	x	x	x
bare.cover	Mean percent bare ground cover on transects	x	x	x	x	x
litter.cover	Mean percent litter cover on transects	x	x	x	x	x
forb.cover	Mean percent forb cover on transects	x	x	x	x	x
Artemisia.cover	Mean percent *Artemisia spp.* cover on transects	x	x	x	x	x
QUGA.cover	Mean percent *Quercus gambelii* cover on transects	x	x	x	x	x
RONE.cover	Mean percent *Robinia neomexicana* cover on transects	x		x	x	x
Holodiscus.cover	Mean percent *Holodiscus spp*. cover on transects	x	x	x	x	x

Variable name	Description	PLC PCA1	PLC PCA2	GFC PCA1	GFC PCA2	PLC-GFC PCA
RIMO.cover	Mean percent *Ribes montigenum* cover on transects	x		x	x	
tall.grass.cover	Mean percent tall grass cover (> 20 cm) on transects	x	x	x	x	x
short.grass.cover	Mean percent short grass cover (< 20 cm) on transects	x	x	x	x	x
shrub.spp.count	Count of shrub species on belt transects	x	x	x	x	x
stump.log.count	Mean count of stumps (dead rooted tree, > 5 cm dbh) and logs (>10 cm width, > 0.5 m long) on belt transects	x	x	x	x	x

Results

Landscape scale

Gray-footed Chipmunk Single-Species Occupancy Models

Gray-footed chipmunk detection model (GFC DM). We detected gray-footed chipmunks on 76 occasions at 43 sites. There were five competitive detection models (Table S8). The model with the highest relative support based on AICc contained no uninformative variables (Table 7) and was the model with the fewest parameters. This model was selected as the top gray-footed chipmunk detection model, and it performed better than the null by Δ 17.57 AICc. The detection of gray-footed chipmunks decreased as the maximum daily temperature increased and when the amount of canopy cover increased at the site, while their detection increased when the amount of rock cover increased at the site (Figure 2).

Table 7. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for the top model describing detection probability (model GFC DM) of the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range, 2019.

Model	Submodel	Variable name	β	SE	85% CI
GFC DM	Detection	Intercept	-1.43	0.22	-1.75, -1.11
		Max. daily temperature	-0.57	0.21	-0.89, -0.26
		Rock cover	0.30	0.15	0.08, 0.53
		Canopy cover	-0.69	0.19	-0.97, -0.41

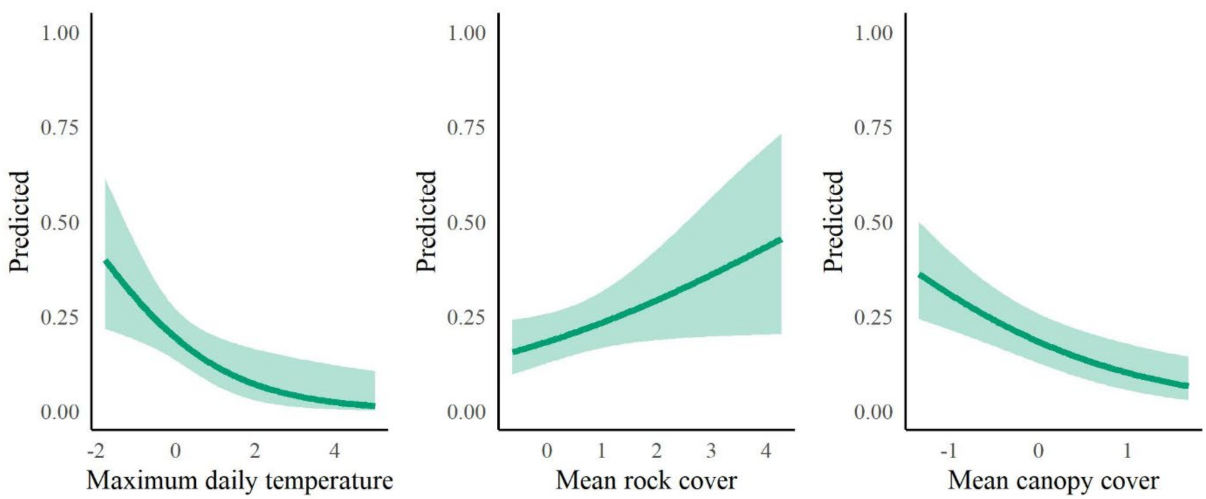

Figure 2. Probability of detection based on the top detection model as a function of maximum daily temperature, rock cover, and canopy cover for gray-footed chipmunk in the contemporary Peñasco least chipmunk range, 2019. Values are expressed as scaled quantities on the x axis. Shading depicts 85% confidence intervals.

Gray-footed chipmunk occupancy models with Peñasco least chipmunk variables (GFC SSOM3 and SSOM14). The gray-footed chipmunk occupancy model that was limited to just the three variables known to influence Peñasco least chipmunk occupancy failed to perform better than the null model (Table S9) and contained uninformative parameters (Table S10). The gray-footed chipmunk occupancy model limited to the 14 variables predicted to be important to the Peñasco least chipmunk resulted in 10 competitive models (Table S11). After eliminating models containing uninformative parameters (Table S12), three competitive models remained which we averaged as the top model (Table 8). The top model included Engelmann spruce dominant forest, herbaceous cover, and elevation. The probability of gray-footed chipmunk occupancy increased at sites with Engelmann-spruce-dominated forest and at higher elevation but decreased at sites with more herbaceous cover (Figure 3).

Table 8. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for the top model describing landscape scale selection (models GFC SSOM 14 and GFC SSOM) by the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range, 2019. *Uninformative variable based on 85% confidence interval.

Model	Submodel	Variable name	β	SE	85% CI
GFC SSOM14	Detection	Intercept	-1.46	0.22	-1.77, -1.14
		Max. daily temperature	-0.57	0.22	-0.89, -0.25
		Rock cover	0.27	0.16	0.05, 0.50
		Canopy cover	-0.77	0.20	-1.05, -0.48
	Occupancy	Intercept	-1.01	0.25	-1.36, -0.65
		Engelmann spruce dominant	0.42	0.66	0.13, 1.98
		Herbaceous cover	-0.52	0.23	-0.85, -0.19
		Elevation	0.15	0.24	0.06, 0.74
GFC SSOM	Detection	Intercept	-1.34	0.22	-1.66, -1.03
		Max. daily temperature	-0.52	0.22	-0.84, -0.21
		Rock cover*	0.20	0.16	-0.03, 0.42
		Canopy cover	-0.70	0.19	-0.98, -0.42
	Occupancy	Intercept	-2.46	0.55	-3.26, -1.66
		Herbaceous cover	-0.68	0.27	-1.07, -0.28
		Boulder height	0.67	0.24	0.33, 1.01
		Montane shrub cover	-2.65	0.80	-3.81, -1.49
		Montane shrub cover ^2	1.12	0.49	0.42, 1.82

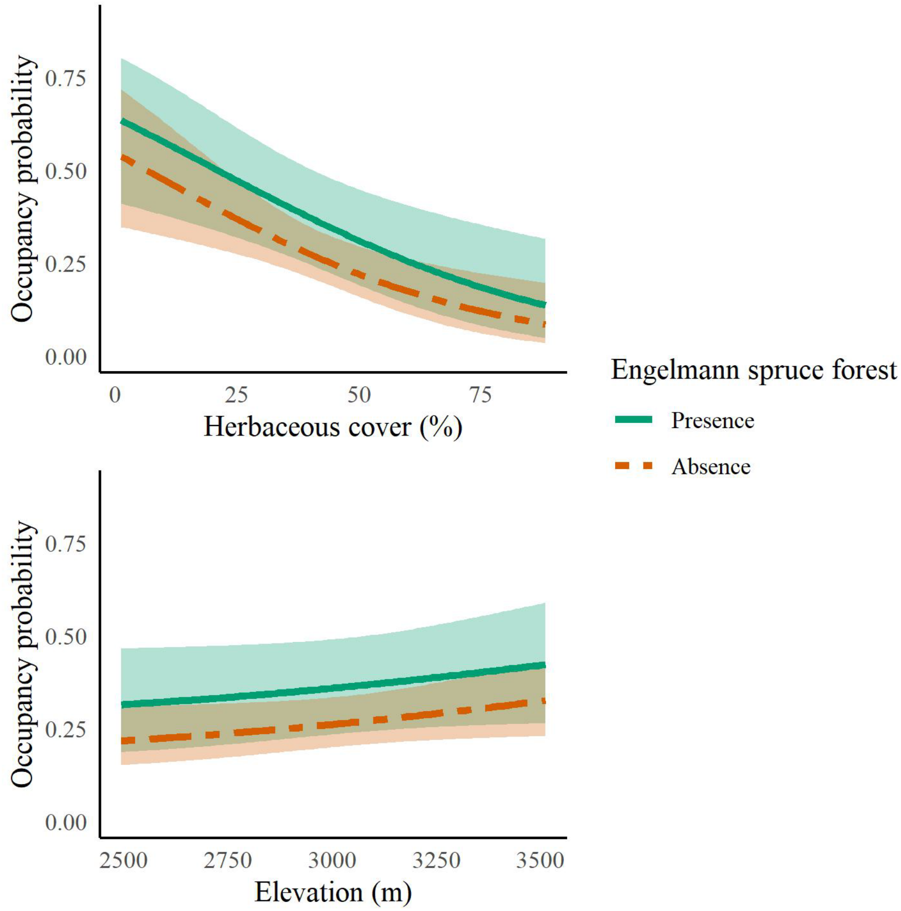

Figure 3. Predicted occupancy probability as a function of variables in the top model describing landscape-scale selection (GFC SSOM14) by the gray-footed chipmunk (GFC) using variables predicted to influence Peñasco least chipmunks in their contemporary range (McKibben & Frey, 2025), 2019. Shading depicts 85% confidence intervals.

Gray-footed chipmunk landscape-scale habitat selection model. There were four competitive models describing gray-footed occupancy within the contemporary Peñasco least chipmunk range (Table S13). After eliminating models with uninformative parameters only one model remained (m15, Table S14) which performed better than the null by Δ 22.93 AICc. This model included herbaceous cover, boulder height, and the quadratic effect of montane shrub cover (Table 8). The probability of gray-footed chipmunk occupancy increased at sites with greater boulder height. Occupancy probability increased at sites with little montane shrub cover but also greatly increased at sites with more than 35% montane shrub cover. Occupancy probability decreased at sites with more herbaceous cover (Figure 4).

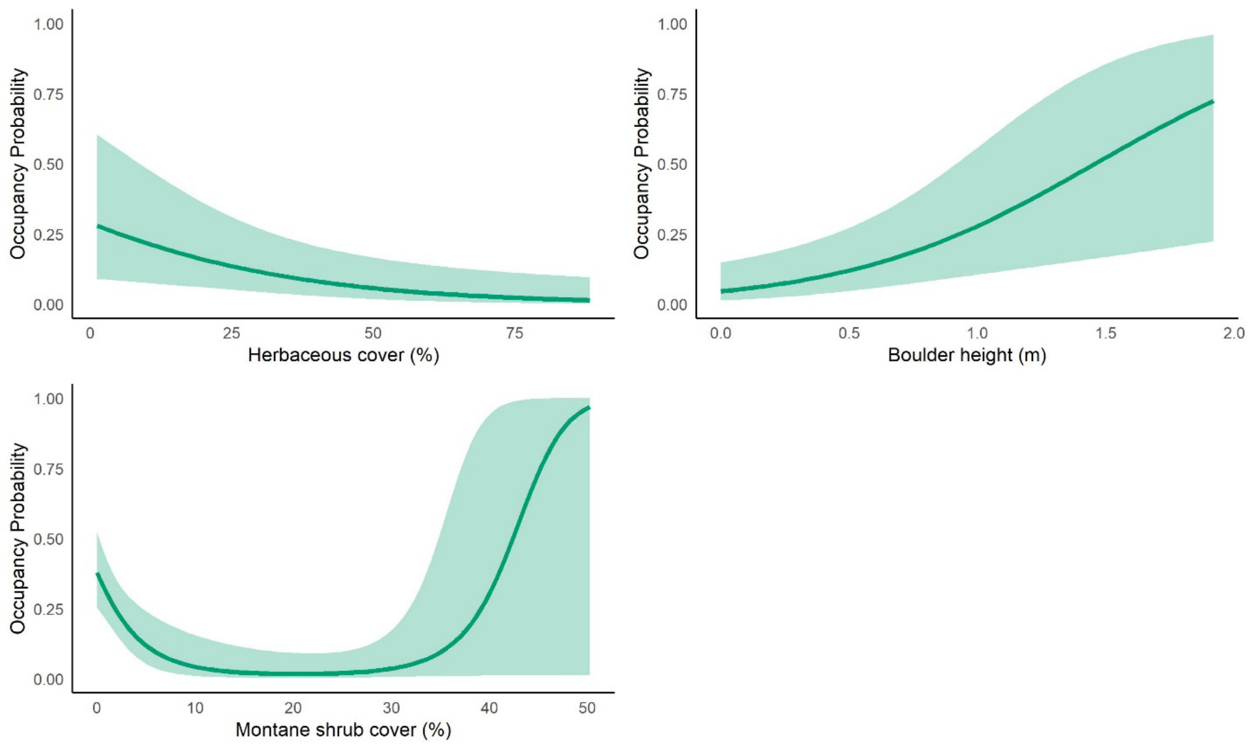

Figure 4. Predicted occupancy probability as a function of variables in the top model describing landscape scale selection (model GFC SSOM) by the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range, 2019. Shading depicts 85% confidence intervals.

Peñasco Least Chipmunk and Gray-footed Chipmunk Multi-species Occupancy Model

There were 30 sites used by gray-footed chipmunks, 18 sites used by Peñasco least chipmunks, 9 sites used by both species, and 174 sites where no chipmunks of either species were detected. None of the *a priori* models assuming independence between species were competitive (Table S15), providing evidence of interspecific dependence in this system. There was only one competitive model, which received 81.2% of the weight (Table S15). The top model included variables describing both marginal and conditional effects. Marginal effects assume that there is no influence of one species on the other, providing equivalent information as if the species were evaluated independently with separate singe species models. In other words, the marginal effects describe the species occupancy without regard for the other species. The top model included marginal effects of herbaceous cover, boulder height, and montane shrub cover for the gray-footed chipmunk and the marginal effects of elevation and small-scale edge for the Peñasco least chipmunk (Table 9). The marginal site occupancy by gray-footed chipmunks increased with increasing boulder height, elevation, and montane shrub cover, but decreased with increasing herbaceous cover (Figure 5). The marginal site occupancy of Peñasco least chipmunks increased with increasing herbaceous cover and elevation, but was not influence by boulder height or montane shrub cover (Figure 5). Occupancy by the gray-footed chipmunk decreased with herbaceous cover regardless of the tree count, but occupancy by the Peñasco least chipmunk had a strong positive response to the amount of herbaceous cover as the count of trees increased, which represented edge habitat at the site (Figure 5).

Table 9. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for the top multi-species occupancy model describing the landscape scale habitat selection (model MSOM) of Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) in the contemporary PLC range, 2019. *Uninformative variable based on 85% confidence interval.

Submodel	Variable	β	SE	85% CI
Detection	[GFC] Intercept	-1.07	0.22	-1.39, -0.75
	[GFC] Canopy cover	-0.76	0.2	-1.04, -0.47
	[PLC] Intercept	-0.84	0.27	-1.22, -0.45
	[PLC] Max. daily temperature	-0.51	0.3	-0.94, -0.09
Occupancy	[GFC] Intercept	-2.8	0.52	-3.55, -2.05
	[GFC] Herbaceous cover	-0.56	0.31	-1.00, -0.12
	[GFC] Boulder height	0.69	0.26	0.32, 1.05
	[GFC] Montane shrub cover	-2.89	0.77	-4.00, -1.77
	[GFC] Montane shrub cover2	1.04	0.3	0.61, 1.47
	[PLC] Intercept	-6.66	1.35	-8.60, -4.71
	[PLC] Elevation	3.75	0.83	2.54, 4.95
	[PLC] Tree count*	-0.95	1.26	-2.76, 0.86
	[PLC] Herbaceous cover	2.33	0.75	1.25, 3.41
	[PLC] Small-scale edge	1.21	0.64	0.30, 2.13
	[GFC:PLC] Intercept	2.71	1.05	1.19, 4.22
	[GFC:PLC] Herbaceous cover	-2.16	0.96	-3.54, -0.78
	[GFC:PLC] Visual obstruction	1.43	0.55	0.64, 2.22

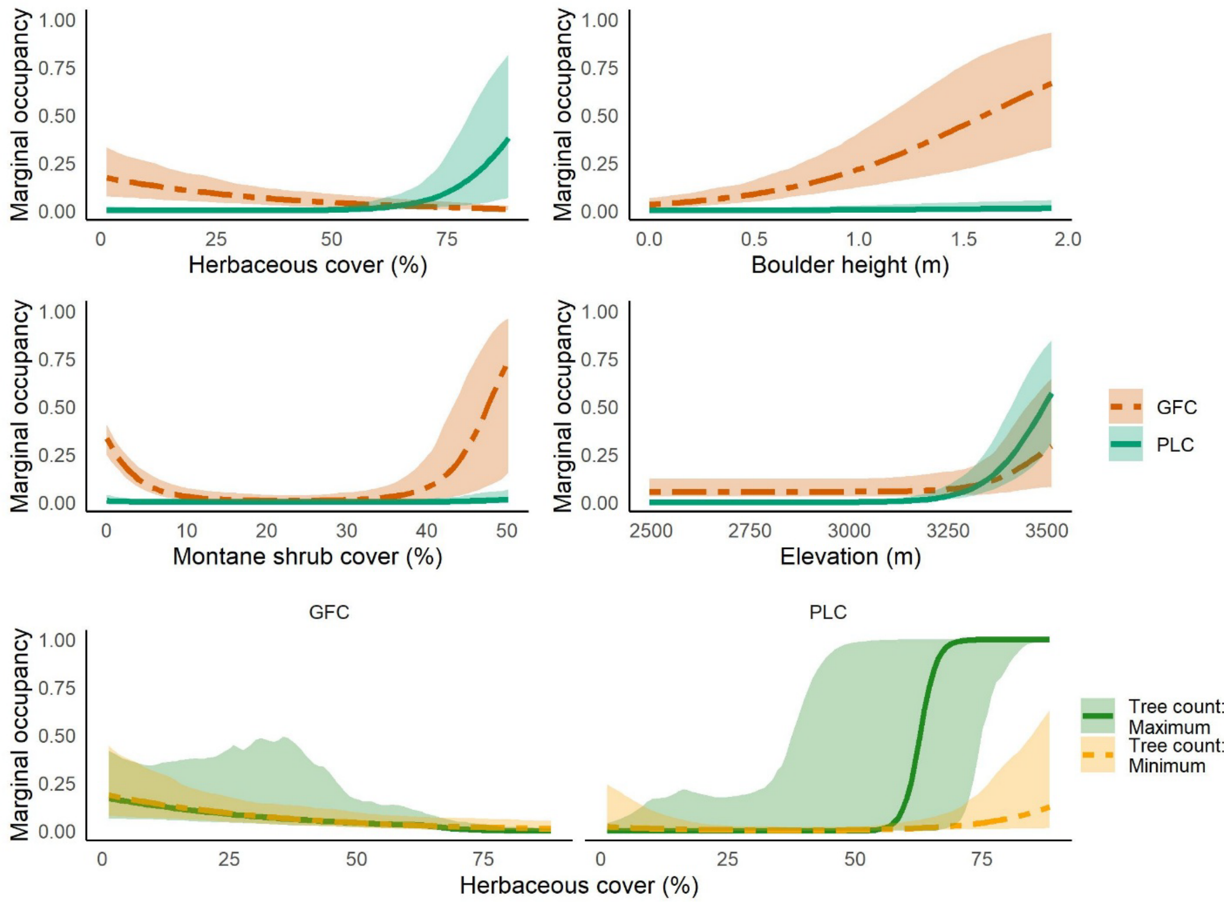

Figure 5. Marginal occupancy probability as a function of variables in the top multi-species occupancy model describing the landscape scale habitat selection (model MSOM) by the Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) in the contemporary PLC range, 2019. Values are expressed as scaled quantities on the x axis. Shading depicts 85% confidence intervals.

The conditional effects in the top multi-species model accounted for the effect that one species has on the other. In other words, the probability of occupancy for one species is conditioned on the presence or absence of the other species at the site. Because we are interested in answering the question of whether competition by gray-footed chipmunks is contributing to a decline of the Peñasco least chipmunk, the top model describes the odds that a site will be used by a Peñasco least chipmunk conditioned on presence of gray-footed chipmunks. The top multi-species model included the conditional effects of herbaceous cover and visual obstruction on odds that a site is used by Peñasco least chipmunks. The odds of Peñasco least chipmunks' use of a site remained unchanged regardless of the amount of visual obstruction in the absence of gray-footed chipmunks, but when gray-footed chipmunks were present, the odds of Peñasco least chipmunks using a site increased with increasing visual obstruction. The odds of Peñasco least chipmunks use of a site increased with increasing herbaceous cover when gray-footed chipmunks were absent, but when gray-footed chipmunks were present, the amount of herbaceous cover had little influence on the odds of Peñasco least chipmunk use (Figure 6).

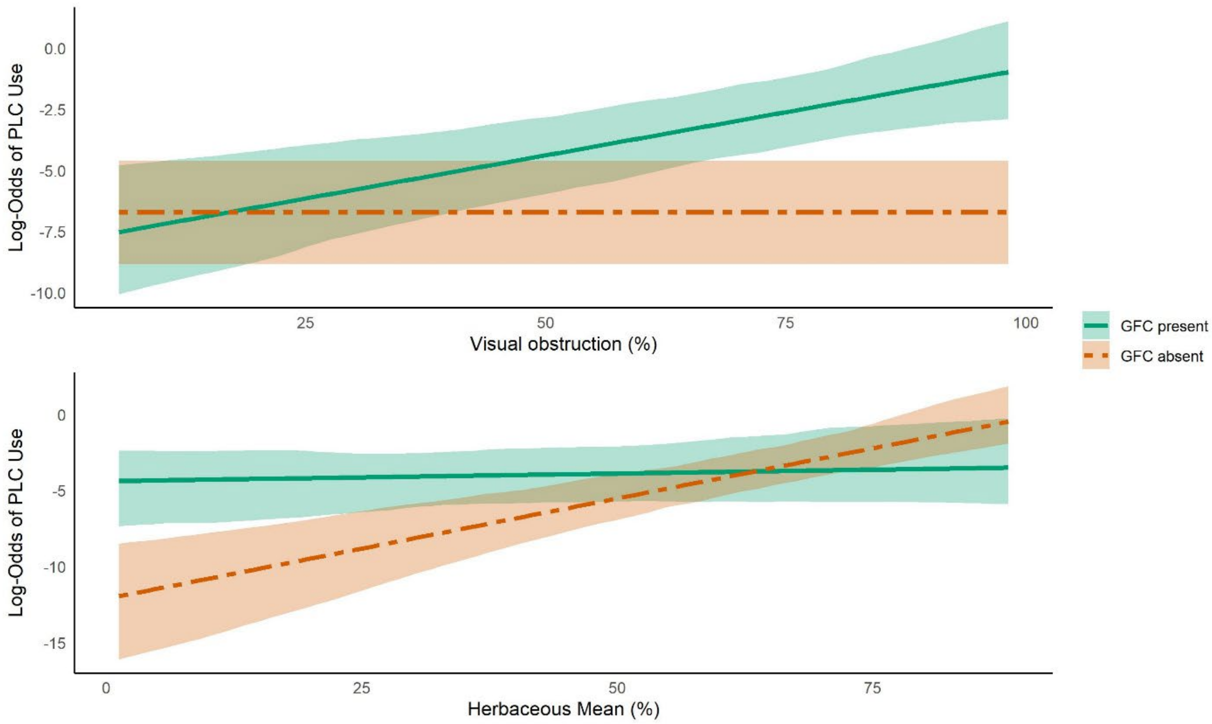

Figure 6. Conditional odds of use as a function of variables in the top multi-species occupancy model describing the landscape scale interaction (model MSOM) between the Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC). These plots illustrate the change in log-odds of PLC use when GFC are absent or present at a site in the contemporary PLC range, Sierra Blanca subrange, 2019. Shading depicts 85% confidence intervals.

Microhabitat scale

Microhabitat selection by Peñasco least chipmunks on Nogal Peak (PLC PCA1 and PLC PCA2). For the PCA based on 9 used sites versus all available sites (PLC PCA1), the first two dimensions accounted for 26.8% of the variation (Figure 7a; Table S16). The scree plot indicated that the first two components were adequate to describe variation among the sites (Figure 7c). Component 1 was strongly influenced by elevation and represented a gradient from low-elevation sites with many trees, stumps, and logs (negative values) to high-elevation sites that are farther from trees with more boulders and shrub cover provided by rockspirea and sagebrush (positive values). Sites used by Peñasco least chipmunks tended to have positive values on component 1. Sites where only habitat data were collected tended to have extremely positive scores on component 1. Component 2 represented a gradient from open sites that were farther from shrubs with more tall grass (negative values) to sites with higher levels of visual obstruction provided by Gambel oak and other montane shrub species (positive values). Sites used by Peñasco least chipmunks tended to have negative scores on component 2. The sites where only habitat data were collected tended to have extremely negative values on component 2.

For the PCA based on 9 used sites versus 9 paired, randomly generated sites (PLC PCA2), the first two dimensions account for 43.3% of the variation (Figure 8a: Table S16). The scree plot indicated that the first two components were adequate to describe variation among the sites (Figure 8c). Component

1 represented a gradient from low-elevation sites with large Gambel oak trees (diameter at breast height [dbh] > 10 cm) with large amounts of stumps, logs, and litter cover (negative values) to high-elevation sites with many boulders and rockspirea cover (positive values). Sites used by Peñasco least chipmunks tended to have positive values on component 1. Component 2 represented a gradient from open areas that were farther from trees and shrubs with large amounts of grass and sagebrush cover (negative values) to sites with high levels of visual obstruction provided by Gambel oak and other montane shrub species (positive values). Sites used by Peñasco least chipmunks tended to have negative scores on component 2.

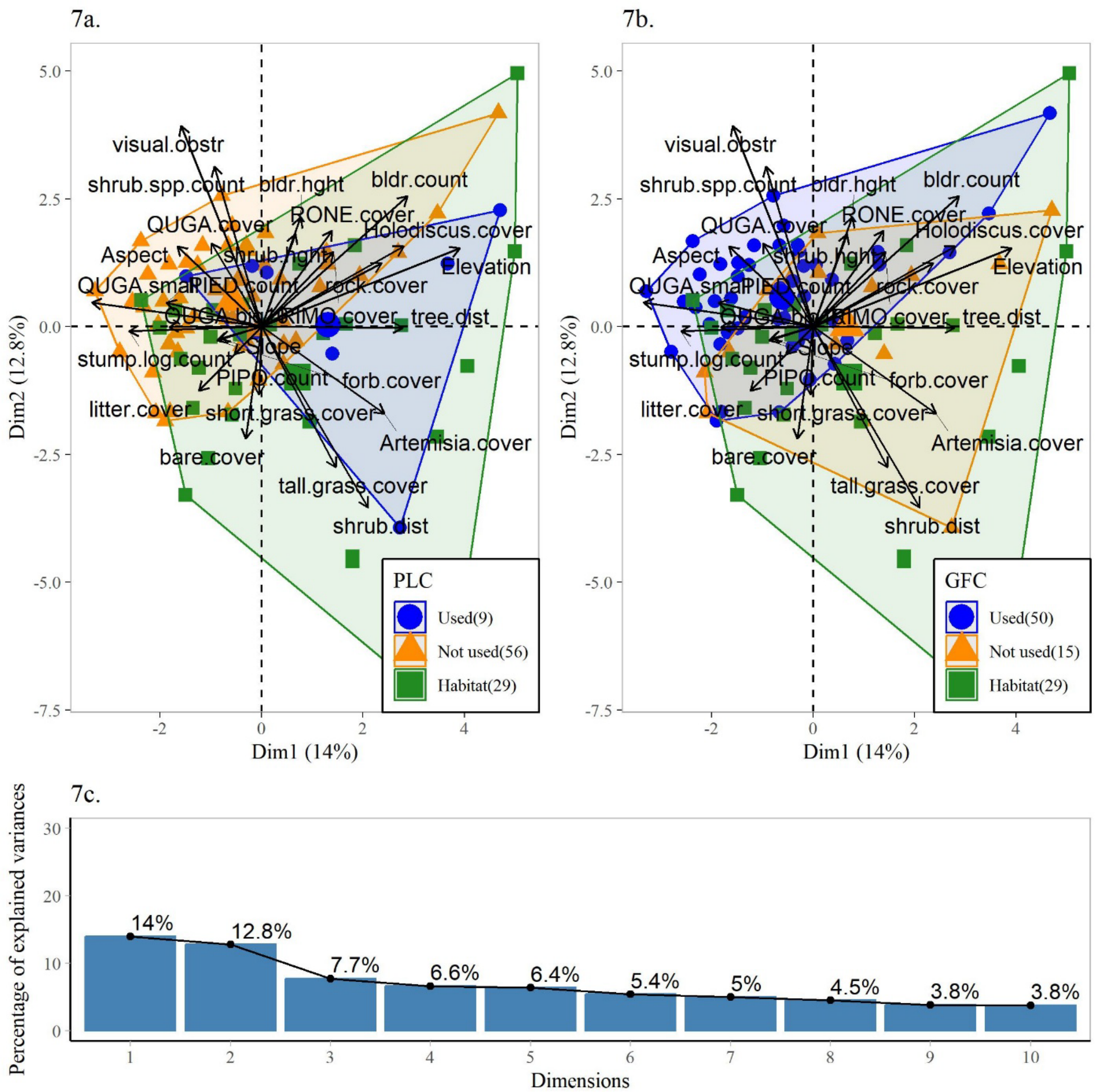

Figure 7a, 7b, and 7c. Biplots and scree plots for principal components analyses (models PLC PCA1 and GFC PCA1) comparing used, not used, and available sites within their habitat that describe patterns of Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) microhabitat selection on Nogal Peak, 2018-2023.

There were four competitive logistic regression models between 9 used and 85 available sites for the Peñasco least chipmunk (PLC REG), all of which ranked higher in relative strength than the null (Table S17). After eliminating models with uninformative variables (Table S18), two competitive models remained. The averaged top model included elevation, folded aspect, and the count of stumps and logs (Table 10). The probability of use of a site by Peñasco least chipmunks increased with increasing elevation and increasing count of stumps and logs but decreased as folded aspect moved away from southwest (Figure 9).

Table 10. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for the top regression model describing microhabitat-scale habitat selection (models PLC REG, GFC REG, and PLC-GFC REG) of the Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) on Nogal Peak, 2018-2023.

Model	Variable name	β	SE	85% CI
PLC REG	Intercept	-2.79	0.54	-3.58, -2.00
	Aspect	-0.73	0.33	-1.21, -0.25
	stump.log.count	-0.88	0.81	-2.25, -0.20
	Elevation	0.17	0.32	0.15, 1.05
GFC REG	Intercept	-0.07	0.29	-0.50, 0.35
	visual.obstr	1.05	0.46	0.38, 1.72
	shrub.spp.count	0.49	0.42	0.19, 1.17
	Artemisia.cover	-1.00	0.45	-1.66, -0.34
	QUGA.small	0.81	0.33	0.34, 1.29
	Slope	0.74	0.32	0.28, 1.20
	stump.log.count	-1.08	0.43	-1.70, -0.46
	PIED.count	0.14	0.28	0.03, 0.99
PLC-GFC REG	Intercept	-2.16	0.49	-2.87, -1.45
	Elevation	0.73	0.50	0.27, 1.48
	visual.obstr	-0.55	0.56	-1.53, -0.36
	Aspect	-0.29	0.41	-1.19, -0.18
	bare.cover	0.15	0.33	0.07, 1.20
	Holodiscus.cover	0.12	0.30	0.29, 1.22

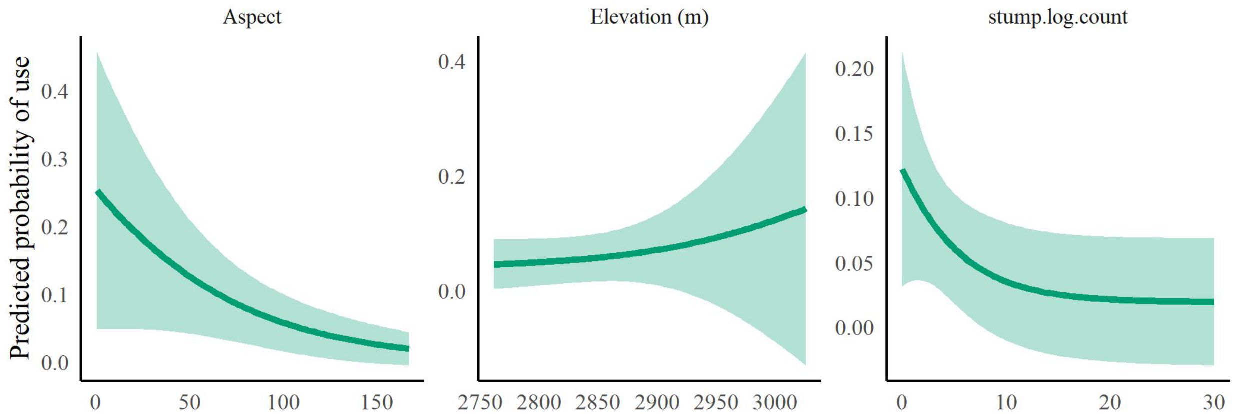

Figure 9. Predicted probability of use as a function of the top regression model (PLC REG) comparing sites used by the Peñasco least chipmunk (*Neotamias minimus atristriatus*) with available sites on Nogal Peak, Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2019. Shading depicts 85% confidence intervals.

Microhabitat selection by gray-footed chipmunks on Nogal Peak. For the first PCA based on 50 used sites versus 44 available sites (GFC PCA1), the first two dimensions accounted for 26.8% of the variation (Figure 7b; Table S19), adequately describing the variation among sites (Figure 7c). We modeled the principal components using the same set of sites, so the first two components represent the same gradients as described above in PLC PCA1. Sites that were used by gray-footed chipmunks tended to have negative values on component 1 and positive values on component 2.

For the PCA based on 22 used sites versus 22 paired, randomly generated sites (GFC PCA2, the first two dimensions accounted for 30.4% of the variation (Figure 8b; Table S19). The scree plot indicated that the first two components were adequate to describe variation among the sites (Figure 8c). Component 1 was strongly influenced by elevation and represented a gradient from low-elevation sites with higher numbers of trees, stumps, and logs (negative values) to high-elevation sites that are farther from trees with more boulders and shrub cover provided by rockspirea and sagebrush (positive values). Sites used by gray-footed chipmunks tended to have negative values on component 1. Component 2 represented a gradient from open areas that were farther from trees and shrubs with large amounts of grass and sagebrush cover (negative values) to sites with higher levels of visual obstruction provided by Gambel oak and other montane shrub species (positive values). Sites used by gray-footed chipmunks tended to have positive scores on component 2.

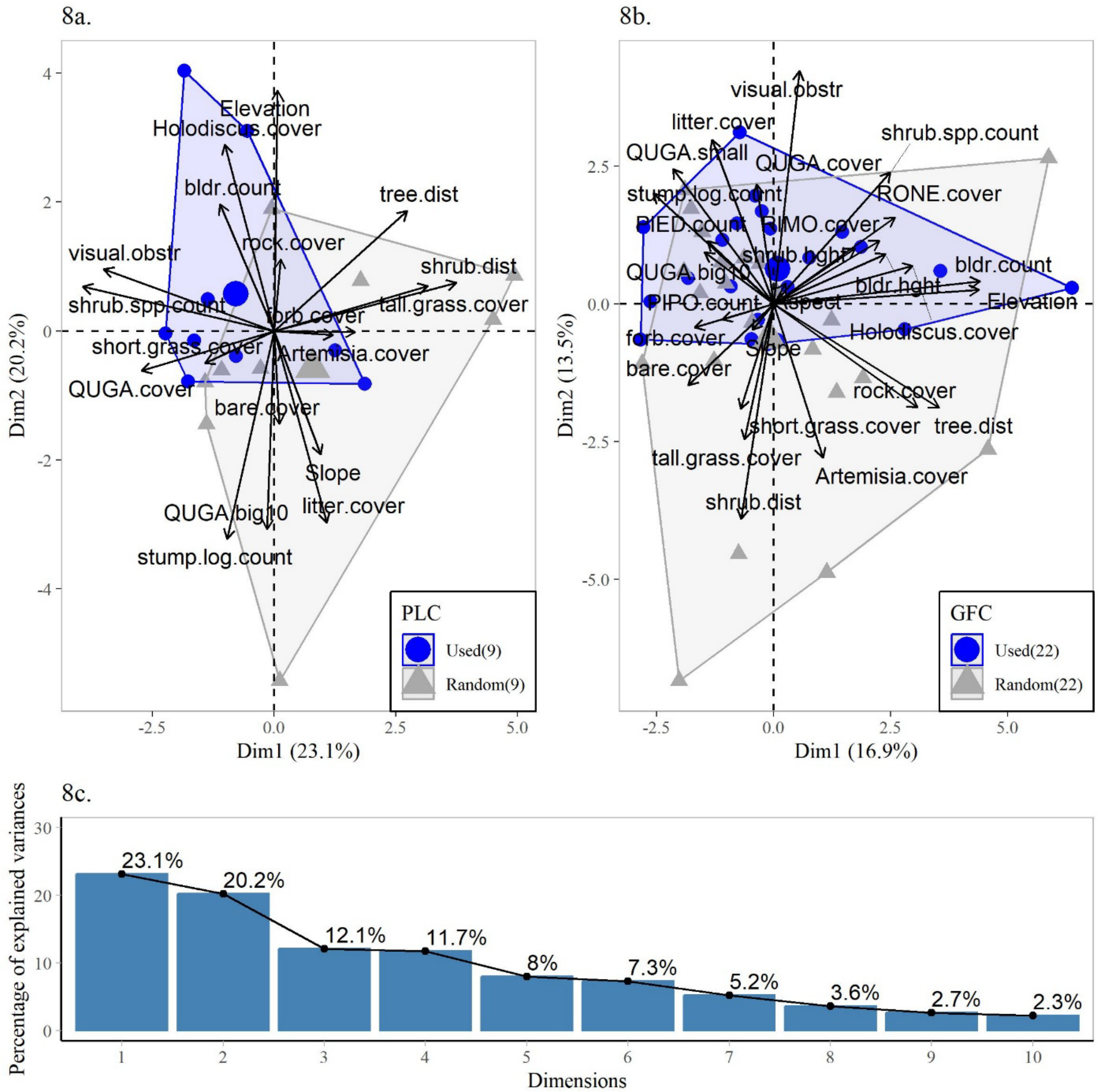

Figure 8a, 8b, and 8c. Biplots and scree plot for Principal Components Analyses (models PLC PCA2 and GFC PCA 2) comparing used sites with paired, randomly-generated sites that describe patterns of Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) microhabitat selection on Nogal Peak, 2018-2023.

There were seven competitive logistic regression models between 50 used sites and 44 available sites for the gray-footed chipmunk (GFC REG), all of which ranked higher in relative strength than the null model (Table S20). After eliminating models with uninformative variables (Table S21), two competitive models remained. The averaged top model included visual obstruction, the count of shrub species, *Artemisia* cover, small (dbh 5-10 cm) Gambel oak cover, slope, count of stumps and logs, and count of pinyon trees (Table 10). The probability of site use by gray-footed chipmunks increased with increasing visual obstruction, number of shrub species, Gambel oak cover, slope, and count of pinyon trees, but decreased with increasing *Artemisia* cover and count of stumps and logs (Figure 10).

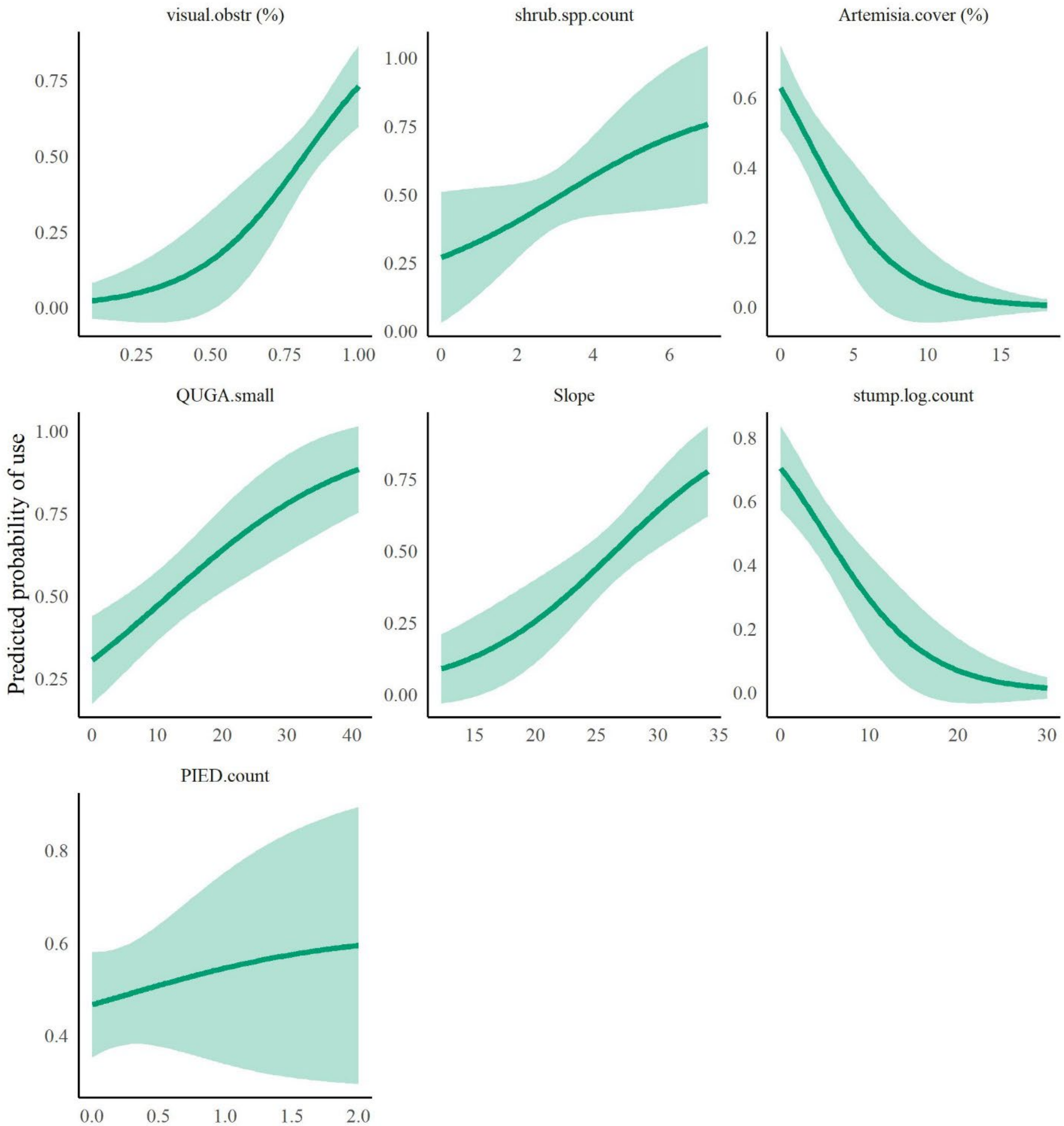

Figure 10. Predicted probability of use as a function of the top regression model (GFC REG) comparing sites used by the gray-footed chipmunk (*Neotamias canipes*) with available sites on Nogal Peak, Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2019. Shading depicts 85% confidence intervals.

Comparison of microhabitat selection between Peñasco least chipmunks and gray-footed chipmunks on Nogal Peak. This PCA compared the species' microhabitat use based on 9 sites used by Peñasco least chipmunks versus 50 sites used by gray-footed chipmunks (PLC-GFC PCA). The first two components accounted for 31% of the variation (Figure 11a; Table S22). The scree plot indicated that the first two components were adequate to describe variation among the sites (Figure 11b). Component 1 represented a gradient from low-elevation sites with higher numbers of trees, stumps, and logs (negative values) to high-elevation sites that are farther away from trees, with more boulders and shrub cover provided by rockspirea and sagebrush (positive values). Sites used by Peñasco least chipmunks tended to have positive values on component 1 and sites used by gray-footed chipmunks tended to have negative scores. Component 2 represented a gradient from open sites that were farther away from shrubs with large amounts of tall grass (negative values) to sites with high levels of visual obstruction provided by Gambel oak and other montane shrub species (positive values). Sites used by Peñasco least chipmunks tended to have negative scores on component 2 and sites used by gray-footed chipmunks tended to have positive scores.

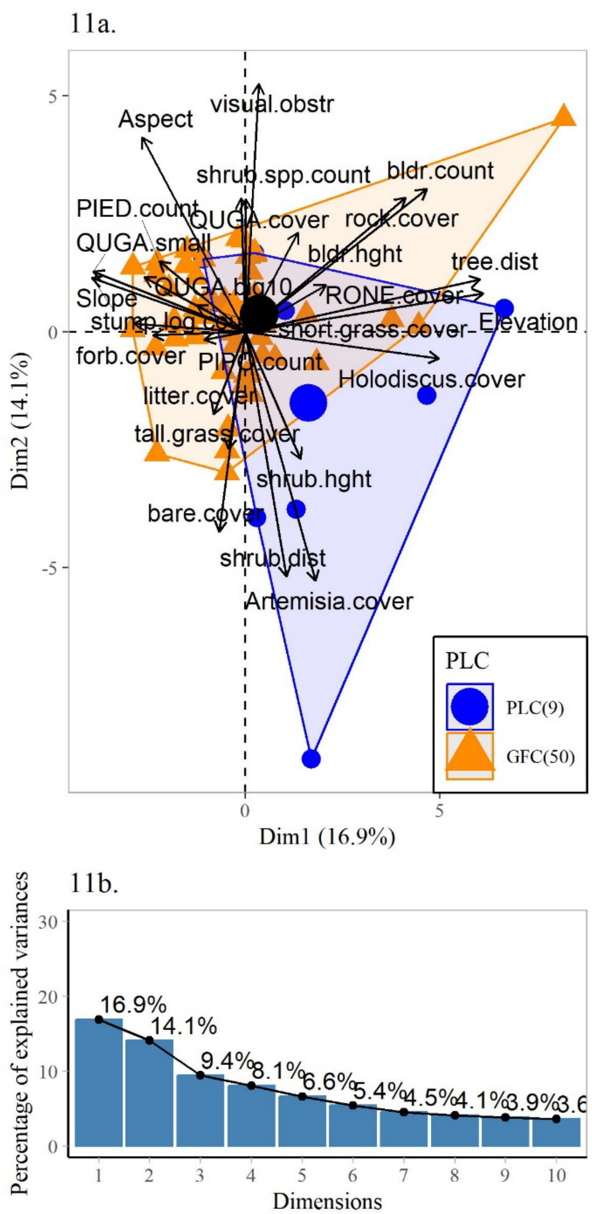

Figure 11a and 11b. Biplot and scree plot for Principal Components Analyses (model PLC-GFC PCA) comparing microhabitat at sites used by Peñasco least chipmunks (PLC) and gray-footed chipmunks (GFC) on Nogal Peak, 2018-2023.

There were twelve competitive logistic regression models comparing 9 sites used by Peñasco least chipmunks and 50 sites used by gray-footed chipmunks (PLC-GFC REG), all of which ranked higher in relative strength than the null model (Table S23). After eliminating models with uninformative variables (Table S24), four competitive models remained. The averaged top model included elevation, visual obstruction, folded aspect, amount of bare cover, and amount of *Holodiscus* cover (Table 10). Sites used by Peñasco least chipmunks (as opposed to those used by gray-footed chipmunks) were at higher elevations with more bare ground and *Holodiscus* cover. Peñasco least chipmunks avoided sites with higher levels of visual obstruction and as the folded aspect increased towards warmer and dryer sites on the southwestern-facing slope (Figure 12).

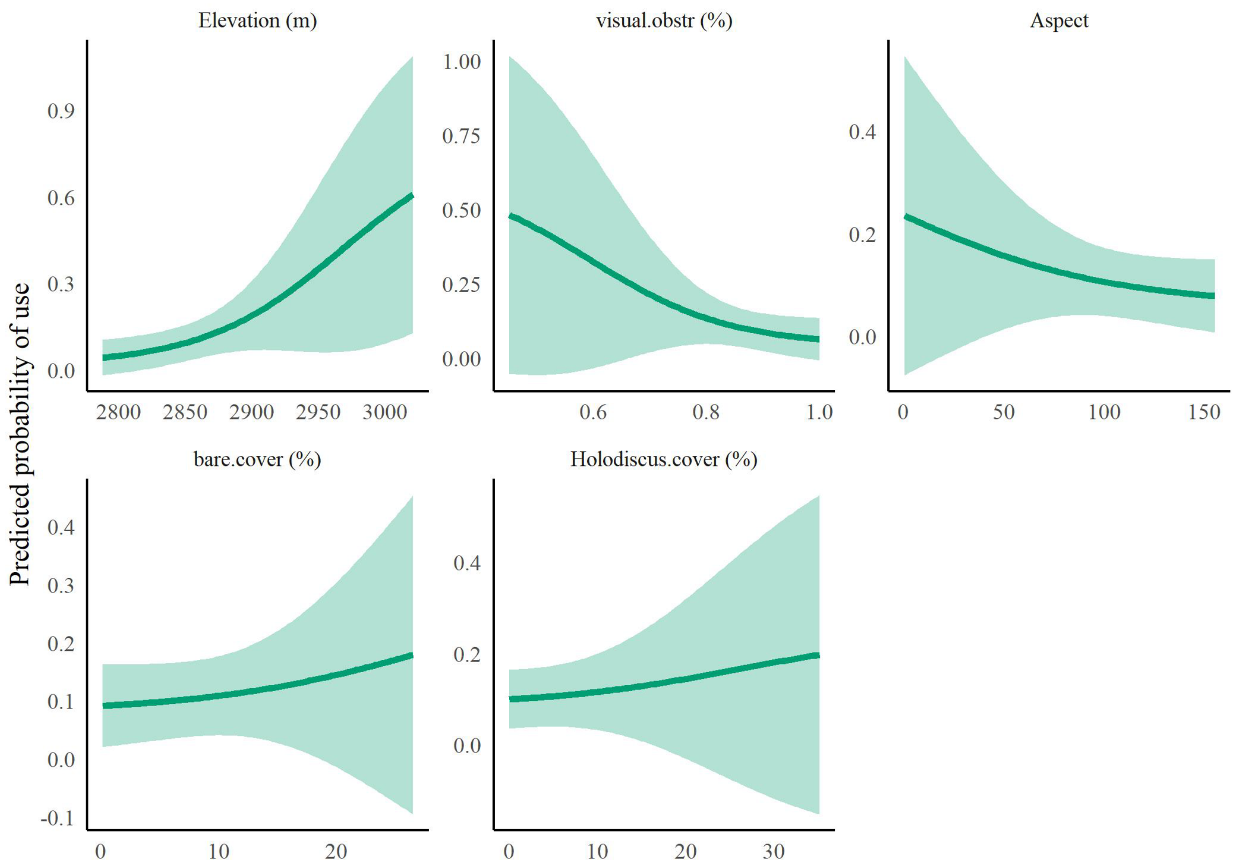

Figure 12. Predicted probability of use as a function of the top regression model (PLC-GFC REG) comparing sites used by the Peñasco least chipmunk (*Neotamias minimus atristriatus*) with sites used by the gray-footed chipmunk (*Neotamias canipes*) on Nogal Peak, Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2019. Shading depicts 85% confidence intervals.

Discussion

We identified overlap of habitat preference between the Peñasco least chipmunk and the gray-footed chipmunk at both scales that we tested. At the landscape scale, occupancy of both species was positively associated with increased elevation and the presence of Engelmann spruce forest. It is unclear what functional role the higher elevation plays, but it may be a proxy for other environmental factors such the associated changes in temperature or plant communities. Because the relic populations of Peñasco least chipmunks are already restricted to the tallest peaks available, elevation represents a likely source of competition between the species. The presence of Engelmann spruce is important to both species, but their preference for these trees is nuanced, represented by the interaction terms in our modeling. Peñasco least chipmunks are closely associated with Engelmann spruce trees when the spruces grow sparsely and are associated with an understory of low-growing shrubs and herbaceous cover; these conditions describe a shrubby meadow with scattered Englemann spruce. Conversely, gray-footed chipmunks prefer Englemann spruce trees when the spruces grow near other trees, creating a closed-canopy stand with sparse undergrowth; these conditions describe a subalpine coniferous forest. Thus, while both species use sites with Englemann spruce where they may co-occur, the subtle difference in the species' association with Engelmann spruce trees could represent a strategy to exploit different niches, reducing the potential for competition.

The results of our multi-species occupancy model (MSOM) supported our prediction that the presence of gray-footed chipmunks influenced the occupancy of Peñasco least chipmunks at the landscape scale. In the absence of gray-footed chipmunks, Peñasco least chipmunks select for higher levels of herbaceous cover, and the amount of visual obstruction has little influence on their occupancy. This is a key finding because it establishes that in the absence of potential competitors, Peñasco least chipmunks are selecting for the herbaceous component of the habitat, not the shrubs. When gray-footed chipmunks are present, the amount of visual obstruction becomes a strong predictor of Peñasco least chipmunk occupancy, while the importance of herbaceous cover at the site declines. Peñasco least chipmunks are altering their behavior based on the presence of the gray-footed chipmunk, prioritizing the visual obstruction provided by shrubs while reducing their selection for herbaceous cover. It appears that when gray-footed chipmunks are present, the need for visual obstruction is so strong that Peñasco least chipmunks must select for it rather than the amount of herbaceous cover. This emphasizes that the herbaceous layer is a key habitat requirement of the Peñasco least chipmunk and that their association with shrubs might be a product of their interaction with the gray-footed chipmunk.

At the microhabitat scale, the results of our analyses suggest that there is broad overlap in microhabitat features used by both the Peñasco least chipmunk and gray-footed chipmunk, but that the species are also segregating the environment though distinct habitat preferences. The Peñasco least chipmunk prefers areas that are more open, are farther from trees, and that have more grass cover and low-growing dense shrubs, particularly sagebrush (*Artemisia* spp.) and rockspirea (*Holodiscus dumosus*). In contrast, the gray-footed chipmunk strongly prefers areas with trees and areas dominated by Gambel oak montane shrubland that have high visual obstruction.

Our results provide strong evidence that there is overlap in the habitat preferences of Peñasco least chipmunks and gray-footed chipmunks at both scales. This overlap indicates that there is potential for competition between the species. Furthermore, the multispecies model indicated that aspects of the

Peñasco least chipmunk's selection for areas with high visual cover was contingent on the presence or absence of the gray-footed chipmunk, which may be interpreted as a product of competition. Dense cover is known to facilitate the co-existence of competing pairs of other rodent species, likely by reducing interspecific contact (e.g., Terman, 1974). Thus, while our results strongly suggest that competition may be occurring, we cannot prove that competition between the species exists without conducting behavioral or removal experiments. Regardless, our results provide important context for understanding how these two species of chipmunks use the environment, and which species may be favored because of environmental change. For instance, the maturing Gamble oak montane scrub woodland on Nogal Peak clearly favors gray-footed chipmunks. A better understanding of the environmental conditions that promote the openings that contain rockspirea or sagebrush, as opposed to mature montane scrub, would benefit the conservation of the Peñasco least chipmunk.

Management recommendations

We recommend that future survey efforts for the Peñasco least chipmunk include high-elevation areas farther from trees and with sagebrush or rockspirea shrubs, and potentially early seral low dense Gamble oak scrub. Management activities should prioritize maintaining or enhancing open areas with high levels of herbaceous cover and low-growing shrubs that provide visual obstruction. We recommend further research on the behavioral interactions between the two species of chipmunks and on environmental factors that lead to key plant communities in the Sierra Blanca subrange, including rockspirea, sagebrush, and various plant communities, growth forms, and disturbance regimes of montane scrub.

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Supplemental Tables

Table S1. List of *a priori* detection models used in model selection for landscape scale detection of the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range in the Sierra Blanca subrange, 2019. "X" indicates that the variable was included in the model. For variable definitions see Table 2.

Model	Scent lure age	Precipitation	Max. daily temp	Seasonality	Rock cover	Canopy cover
m01						
m02						x
m03			x			
m04			x			x
m05		x				
m06		x				x
m07		x	x			
m08		x	x			x
m09					x	
m10					x	x
m11			x		x	
m12			x		x	x
m13		x			x	
m14		x			x	x
m15		x	x		x	
m16		x	x		x	x
m17	x					
m18	x					x
m19	x		x			
m20	x		x			x
m21	x	x				
m22	x	x				x
m23	x	x	x			
m24	x	x	x			x
m25	x				x	
m26	x				x	x
m27	x		x		x	
m28	x		x		x	x
m29	x	x			x	
m30	x	x			x	x

Model	Scent lure age	Precipitation	Max. daily temp	Seasonality	Rock cover	Canopy cover
m31	x	x	x		x	
m32	x	x	x			
m33	x	x	x		x	x
m34				x		
m35			x	x		
m36			x	x		x
m37		x		x		
m38		x		x		x
m39		x	x	x		
m40		x	x	x		x
m41				x	x	
m42				x	x	x
m43			x	x	x	
m44			x	x	x	x
m45		x		x	x	
m46		x		x	x	x
m47		x	x	x	x	
m48		x	x	x	x	x
m49	x			x		
m50	x			x		x
m51	x		x	x		
m52	x		x	x		x
m53	x	x		x		
m54	x	x		x		x
m55	x	x	x	x		
m56	x	x	x	x		x
m57	x			x	x	
m58	x			x	x	x
m59	x		x	x	x	
m60	x		x	x	x	x
m61	x	x		x	x	
m62	x	x		x	x	x
m63	x	x	x	x	x	
m64	x	x	x	x	x	x

Table S2. List of *a priori* models used in model selection for landscape scale habitat selection of the gray-footed chipmunk (*Neotamias canipes*) in the contemporary Peñasco least chipmunk range in the Sierra Blanca subrange (model GFC DM), Sacramento Mountains, New Mexico, USA, 2019. "X" indicates that the variable was included in the model.

	Detection			Occupancy				
Model	Max. daily temp	Rock cover	Canopy cover	Herbaceous cover	Engelmann spruce forest	Boulder height	Montane shrub cover	Gooseberry currant cover
m01	x	x	x					
m02	x	x	x				x	
m03	x	x	x	x			x	
m04	x	x	x		x		x	
m05	x	x	x			x	x	
m06	x	x	x	x	x	x		
m07	x	x	x	x	x		x	
m08	x	x	x		x	x		
m09	x	x	x			x		
m10	x	x	x		x			
m11	x	x	x	x				
m12	x	x	x	x	x			
m13	x	x	x	x		x		
m14	x	x	x		x	x	x	
m15	x	x	x	x		x	x	
m16	x	x	x				x	x
m17	x	x	x	x			x	x
m18	x	x	x		x		x	x
m19	x	x	x			x	x	x
m20	x	x	x	x	x	x		
m21	x	x	x	x	x		x	x
m22	x	x	x		x	x		
m23	x	x	x			x		
m24	x	x	x		x			
m25	x	x	x	x				
m26	x	x	x	x	x			
m27	x	x	x	x		x		
m28	x	x	x		x	x	x	x
m29	x	x	x	x		x	x	x
m30	x	x	x	x	x	x		
m31	x	x	x	x	x	x	x	
m32	x	x	x	x	x	x	x	x

Table S3. Relative strength of detection variables for gray-footed chipmunk and Peñasco least chipmunk ranked by AICc in the Sierra Blanca subrange, Sacramento Mountains, 2019. For variable definitions see Table 2.

Species	Model	ΔAICc
Gray-footed chipmunk		
	Canopy cover	0.00
	Rock cover	1.25
	Max. daily temp	9.62
	Null	9.85
Peñasco least chipmunk		
	Max. daily temp	0.00
	Precipitation	4.58
	Scent lure age	9.30
	Null	9.46

Table S4. List of *a priori* models used in model selection for Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) multispecies occupancy models in the contemporary Peñasco least chipmunk range (model MSOM), Sierra Blanca subrange, 2019. "X" indicates that the variable was included in the model. For variable definitions see Table 5.

	Detection		Occupancy													
	GFC	PLC	GFC				PLC					Both				
Model	Canopy cover	Max. daily temperature	Small scale edge	Herbaceous cover	Boulder height	Montane shrub cover	Elevation	Visual obstruction	Small scale edge	Herbaceous cover	Boulder height	Herbaceous cover	Elevation	Visual obstruction	Small scale edge
1	x	x													
2	x	x	x												
3	x	x		x											
4	x	x			x										
5	x	x				x									
6	x	x					x								
7	x	x						x							
8	x	x							x						
9	x	x								x					
10	x	x									x				
11	x	x										x			
12	x	x											x		
13	x	x												x	
14	x	x													x
15	x	x	x						x						
16	x	x		x						x					
17	x	x			x						x				
18	x	x				x									
19	x	x	x				x								
20	x	x	x		x		x								
21	x	x	x			x	x								
22	x	x		x	x		x								
23	x	x		x		x	x								
24	x	x			x	x	x								
25	x	x	x				x	x							
26	x	x	x		x		x		x						
27	x	x	x			x	x				x				
28	x	x		x	x		x			x	x				
29	x	x		x		x	x			x					
30	x	x			x	x	x								

Model	Canopy cover	Max. daily temperature	Small scale edge	Herbaceous cover	Boulder height	Montane shrub cover	Elevation	Visual obstruction	Small scale edge	Herbaceous cover	Boulder height	Herbaceous cover	Elevation	Visual obstruction	Small scale edge
31	x	x	x					x	x						
32	x	x	x		x				x		x				
33	x	x	x			x			x	x					
34	x	x		x	x					x	x				
35	x	x		x		x				x					
36	x	x			x	x				x	x				
37	x	x	x					x		x					
38	x	x	x		x				x	x					
39	x	x	x			x				x	x				
40	x	x		x	x		x			x					
41	x	x		x		x				x					
42	x	x			x	x					x		x		x
43	x	x	x				x						x		x
44	x	x	x		x		x						x		x
45	x	x	x			x	x						x		x
46	x	x		x	x		x						x		x
47	x	x		x		x	x						x		x
48	x	x			x	x	x						x		x
49	x	x	x				x	x					x		x
50	x	x	x		x		x		x				x		x
51	x	x	x			x	x				x		x		x
52	x	x		x	x		x			x	x		x		x
53	x	x		x		x	x			x			x		x
54	x	x			x	x	x						x		x
55	x	x	x					x	x				x		x
56	x	x	x		x				x		x		x		x
57	x	x	x			x			x	x			x		x
58	x	x		x	x					x	x		x		x
59	x	x		x		x				x			x		x
60	x	x			x	x				x	x		x		x
61	x	x	x					x		x			x		x
62	x	x	x		x				x	x			x		x
63	x	x	x			x				x	x		x		x
64	x	x		x	x		x			x			x		x
65	x	x		x		x				x			x		x
66	x	x			x	x					x		x	x	
67	x	x	x				x						x	x	
68	x	x	x		x		x						x	x	

Model	Canopy cover	Max. daily temperature	Small scale edge	Herbaceous cover	Boulder height	Montane shrub cover	Elevation	Visual obstruction	Small scale edge	Herbaceous cover	Boulder height	Herbaceous cover	Elevation	Visual obstruction	Small scale edge
69	x	x	x			x	x						x	x	
70	x	x		x	x		x						x	x	
71	x	x		x		x	x						x	x	
72	x	x			x	x	x						x	x	
73	x	x	x				x	x					x	x	
74	x	x	x		x		x		x				x	x	
75	x	x	x			x	x				x		x	x	
76	x	x		x	x		x			x	x		x	x	
77	x	x		x		x	x			x			x	x	
78	x	x			x	x	x						x	x	
79	x	x	x					x	x				x	x	
80	x	x	x		x				x		x		x	x	
81	x	x	x			x			x	x			x	x	
82	x	x		x	x					x	x		x	x	
83	x	x		x		x				x			x	x	
84	x	x			x	x				x	x		x	x	
85	x	x	x					x		x			x	x	
86	x	x	x		x				x	x			x	x	
87	x	x	x			x				x	x		x	x	
88	x	x		x	x		x			x			x	x	
89	x	x		x		x				x			x	x	
90	x	x			x	x					x		x		x
91	x	x	x				x						x		x
92	x	x	x		x		x						x		x
93	x	x	x			x	x						x		x
94	x	x		x	x		x						x		x
95	x	x		x		x	x						x		x
96	x	x			x	x	x						x		x
97	x	x	x				x	x					x		x
98	x	x	x		x		x		x				x		x
99	x	x	x			x	x				x		x		x
100	x	x		x	x		x			x	x		x		x
101	x	x		x		x	x			x			x		x
102	x	x			x	x	x						x		x
103	x	x	x					x	x				x		x
104	x	x	x		x				x		x		x		x
105	x	x	x			x			x	x			x		x
106	x	x		x	x					x	x		x		x

Model	Canopy cover	Max. daily temperature	Small scale edge	Herbaceous cover	Boulder height	Montane shrub cover	Elevation	Visual obstruction	Small scale edge	Herbaceous cover	Boulder height	Herbaceous cover	Elevation	Visual obstruction	Small scale edge
107	x	x		x		x				x			x		x
108	x	x			x	x				x	x		x		x
109	x	x	x					x		x			x		x
110	x	x	x		x				x	x			x		x
111	x	x	x			x				x	x		x		x
112	x	x		x	x		x			x			x		x
113	x	x		x		x				x			x		x
114	♠	♠			♠	♠					♠		♠	♠	♠
115	♠	♠		♠	♠		♠	♠	♠				♠	♠	♠
116	♠	♠		♠	♠		♠	♠	♠						
117	♠	♠		♠	♠	♠	♠		♠			♠		♠	
118	♠	♠		♠	♠	♠	♠		♠				♠		♠
119	♠	♠		♠	♠	♠	♠		♠					♠	
120	♠	♠		♠	♠	♠	♠		♠			♠			♠

Table S5. List of *a priori* models used in logistic regression analysis of microhabitat scale habitat selection of the Peñasco least chipmunk on Nogal Peak (model PLC REG), Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2018-2023. "X" indicates that the variable was included in the model. For variable definitions see Table 6.

	Variable				
Model	Holodiscus. cover	Elevation	Aspect	stump.log. count	QUGA. small
0					
1	x				
2		x			
3			x		
4				x	
5					x
6		x	x		
7		x		x	
8			x	x	
9		x	x	x	
10	x	x			
11	x		x		
12	x	x	x		
13	x	x		x	
14	x		x	x	
15	x	x	x	x	
16		x			x
17			x		x
18		x	x		x
19		x		x	x
20			x	x	x
21		x	x	x	x
22			x		x
23	x	x		x	
24	x		x		x
25	x	x	x		x
26	x	x		x	x
27	x		x	x	x
28	x	x			x
29			x	x	x
30	x			x	
31	x				x
32	x	x	x	x	x

Table S6. List of *a priori* models used in logistic regression analysis of microhabitat scale habitat selection of the gray-footed chipmunk (GFC) on Nogal Peak (model GFC REG), Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2018-2023. "X" indicates that the variable was included in the model. For variable definitions see Table 6.

	Variable												
Model	visual.obstr	shrub.spp.count	shrub.dist	bare.cover	Artemisia.cover	QUGA.small	tree.dist	Slope	PIED.count	stump.log.count	forb.cover	QUGA.cover	QUGA.big10
0													
1	x												
2	x	x											
3						x						x	x
4	x	x					x		x				x
5	x	x	x										
6	x	x		x									
7	x	x			x								
8	x	x	x		x								
9	x	x			x	x							
10	x	x	x		x	x							
11	x	x			x	x	x						
12	x	x	x		x	x	x						
13	x	x			x	x		x					
14	x	x	x		x	x		x					
15	x	x			x	x		x	x				
16	x	x	x		x	x		x	x				
17	x	x			x	x		x		x			
18	x	x	x		x	x		x		x			
19	x	x			x	x		x		x	x		
20	x	x		x	x	x		x		x			
21	x	x			x	x	x	x		x			
22	x	x			x	x		x		x		x	
23	x	x			x	x		x	x	x			
24				x		x	x			x	x		
25			x	x		x	x			x	x		
26	x	x			x	x		x		x			x
27	x	x			x	x	x	x					
28	x	x	x		x	x	x	x					
29	x			x	x	x	x	x		x			
30		x		x	x	x	x	x		x			
31	x				x	x	x	x		x			

Model	visual.obstr	shrub.spp.count	shrub.dist	bare.cover	Artemisia.cover	QUGA.small	tree.dist	Slope_100M	PIED.count	stump.log.count	forb.cover	QUGA.cover	QUGA.big10
32	x		x		x	x	x	x		x			
33		x			x	x	x	x		x			
34		x	x		x	x	x	x		x			
35	x	x				x	x	x		x		x	
36	x			x	x	x		x		x			x
37		x		x			x	x					x
38		x	x	x			x	x					x
39		x			x		x			x	x	x	
40		x	x		x		x			x	x	x	
41	x				x	x		x	x	x			
42	x		x		x	x		x	x	x			
43	x				x	x		x	x		x		
44	x		x		x	x		x	x		x		
45	x					x		x	x			x	x
46	x		x			x		x	x			x	x
47		x			x		x		x				
48		x	x		x		x		x				
49					x	x	x	x		x			
50			x		x	x	x	x		x			
51		x			x		x		x		x		
52		x	x		x		x		x		x		
53	x					x	x	x	x	x			x
54	x			x	x	x		x		x			
55	x		x	x	x	x		x		x			
56	x			x	x	x				x			
57	x		x	x	x	x				x			
58	x					x	x		x				x
59	x		x			x	x		x				x
60		x			x		x		x			x	x
61		x	x		x		x		x			x	x
62		x				x	x		x				x
63		x	x			x	x		x				x
64		x		x	x						x	x	
65		x	x	x	x						x	x	
66		x			x	x	x	x	x	x			
67	x				x	x	x	x	x	x			
68			x	x	x						x	x	

Model	visual.obstr	shrub.spp.count	shrub.dist	bare.cover	Artemisia.cover	QUGA.small	tree.dist	Slope_100M	PIED.count	stump.log.count	forb.cover	QUGA.cover	QUGA.big10
69		x	x				x		x				x
70			x			x	x		x				x
71					x		x		x			x	x
72			x			x	x		x				x
73		x		x	x	x					x	x	x
74			x	x	x			x			x	x	

Table S7. List of *a priori* models used in logistic regression analysis comparing microhabitat scale habitat selection of the Peñasco least chipmunk with the gray-footed chipmunk on Nogal Peak (model PLC-GFC REG), 2018-2023. “X” indicates that the variable was included in the model. For variable definitions see Table 6.

	Variable											
Model	Aspect	Elevation	visual.obstr	Holodiscus.cover	QUGA.small	Slope	stump.log.count	Artemisia.cover	shrub.spp.count	shrub.dist	bare.cover	tree.dist
0												
1	x											
2		x										
3			x									
4				x								
5					x							
6						x						
7							x					
8								x				
9									x			
10										x		
11											x	
12												x
13	x	x										
14		x	x									
15	x	x									x	
16		x	x								x	
17	x	x							x			
18		x	x						x			
19	x	x					x					
20		x	x				x					
21	x	x			x							
22		x	x		x							
23	x	x		x								
24		x	x	x								
25	x		x			x	x					x
26	x		x				x			x		x
27	x	x	x	x	x					x		
28	x	x	x							x		
29	x	x	x	x	x				x			
30	x	x	x									
31	x	x					x				x	

Model	Aspect_100M	Elevation	visual.obstr	Holodiscus.cover	QUGA.small	Slope_100M	stump.log.count	Artemisia.cover	shrub.spp.count	shrub.dist	bare.cover	tree.dist
32			x								x	x
33	x	x						x				
34		x	x					x				
35	x						x					x
36		x	x		x		x					
37	x	x				x						
38		x	x			x						
39	x	x			x							
40		x	x	x	x							
41			x	x								
42			x		x							
43			x					x				
44			x						x			
45			x	x	x			x				
46			x	x	x			x	x			
47				x				x				
48				x	x			x				
49					x		x			x	x	x
50						x	x			x	x	x
51								x			x	x
52								x			x	
53	x					x						
54	x	x				x			x			
55	x	x	x		x		x	x				

Table S8. Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null detection models describing landscape scale detection of the gray-footed chipmunk in the contemporary Peñasco least chipmunk range, 2019. "X" indicates that the variable was included in the model. For variable descriptions see Table 2.

Model	Scent lure age	Precipitation	Max. daily temp	Seasonality	Rock cover	Canopy cover	df	ΔAICc	AICc weight
m12			x		x	x	5	0.00	0.18
m16		x	x		x	x	6	0.50	0.14
m44			x	x	x	x	6	1.12	0.10
m28	x		x		x	x	6	1.77	0.07
m48		x	x	x	x	x	7	1.98	0.07
m01							2	17.57	0

Table S9. Variables, degrees of freedom (df), ΔAICc, and AICc weight for occupancy models describing landscape scale selection(model GFC SSOM3) by the gray-footed chipmunk using variables known to influence Peñasco least chipmunks in their contemporary range (McKibben and Frey 2025), 2019. "X" indicates that the variable was included in the model. For variable descriptions see Table 3.

	Detection			Occupancy							
Model	Max. daily temp	Rock cover	Canopy cover	Elevation	Visual obstruction	Small-scale edge	Tree count	Herbaceous cover	df	ΔAICc	weight
m01	x	x	x						5.00	0.00	0.59
m02	x	x	x	x	x	x	x	x	10.00	0.73	0.41

Table S10. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for models describing landscape scale selection by the gray-footed chipmunk (GFC) using variables known to influence Peñasco least chipmunks in their contemporary range (model GFC SSOM3), Sierra Blanca subrange, Sacramento Mountains, New Mexico, USA, 2019 (McKibben & Frey, 2025). *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 3.

Model	Submodel	Variable name	β	SE	85% CI
m01	Detection	Intercept	-1.43	0.22	-1.75, -1.11
		Max. daily temperature	-0.57	0.22	-0.89, -0.26
		Rock cover	0.31	0.15	0.09, 0.53
		Canopy cover	-0.69	0.19	-0.97, -0.41
	Occupancy	Intercept	-0.90	0.23	-1.24, -0.57
m02	Detection	Intercept	-1.41	0.22	-1.73, -1.09
		Max. daily temperature	-0.54	0.23	-0.87, -0.22
		Rock cover	0.25	0.16	0.02, 0.47
		Canopy cover	-0.74	0.20	-1.03, -0.45
	Occupancy	Intercept	-0.97	0.27	-1.36, -0.57
		Elevation	0.46	0.27	0.06, 0.85
		Visual obstruction*	0.22	0.23	-0.11, 0.55
		Small-scale edge*	0.12	0.27	-0.26, 0.50
		Tree count*	0.00	0.38	-0.55, 0.56
		Herbaceous cover	-0.60	0.25	-0.97, -0.24

Table S11. Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null occupancy models (model GFC SSOM14) describing landscape scale selection by the gray-footed chipmunk (GFC) using variables predicted to influence Peñasco least chipmunks in their contemporary range (McKibben & Frey, 2025), 2019. "X" indicates that the variable was included in the model. For variable descriptions see Table 3.

	Detection			Occupancy									
Model	Max. daily temp	Rock cover	Canopy cover	Elevation	Visual obstruction	Mixed understory cover	Shrub cover	Herbaceous cover	Dead tree count	Engelmann spruce dominant	df	ΔAICc	weight
m28	x	x	x		x	x	x	x		x	10	0.00	0.09
m32	x	x	x					x		x	7	0.67	0.06
m40	x	x	x	x				x			7	0.82	0.06
m02	x	x	x		x	x	x	x			9	0.97	0.05
m37	x	x	x	x	x	x	x	x			10	1.16	0.05
m20	x	x	x		x	x	x	x	x		10	1.55	0.04
m25	x	x	x					x	x		7	1.77	0.04
m05	x	x	x					x			6	1.77	0.04
m31	x	x	x			x	x	x		x	9	1.77	0.04
m73	x	x	x					x	x	x	8	1.79	0.04
m01	x	x	x								5	5.11	0.01

Table S12. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for competitive (AICc delta < 2) models describing landscape scale selection (GFC SSOM14) by the gray-footed chipmunk (GFC) using variables predicted to influence Peñasco least chipmunks in their contemporary range (McKibben & Frey, 2025), 2019. *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 3.

Model	Submodel	Variable name	β	SE	85% CI
m28	Detection	Intercept	-1.46	0.22	-1.77, -1.14
		Max. daily temperature	-0.57	0.22	-0.89, -0.25
		Rock cover	0.25	0.16	0.02, 0.48
		Canopy cover	-0.77	0.20	-1.06, -0.49
	Occupancy	Intercept	-1.26	0.28	-1.66, -0.85
		Engelmann spruce dominant	1.04	0.62	0.14, 1.93
		Visual obstruction	0.54	0.29	0.13, 0.95
		Herbaceous cover	-0.84	0.30	-1.28, -0.41
		Shrub cover	-0.84	0.36	-1.35, -0.32
		Mixed understory cover*	-0.27	0.28	-0.67, 0.14
m32	Detection	Intercept	-1.50	0.22	-1.81, -1.18
		Max. daily temperature	-0.58	0.22	-0.89, -0.26
		Rock cover	0.28	0.15	0.06, 0.51
		Canopy cover	-0.80	0.20	-1.09, -0.52
	Occupancy	Intercept	-1.07	0.25	-1.42, -0.71
		Engelmann spruce dominant	1.05	0.64	0.13, 1.98
		Herbaceous cover	-0.49	0.23	-0.82, -0.16
m40	Detection	Intercept	-1.44	0.22	-1.75, -1.13
		Max. daily temperature	-0.52	0.22	-0.84, -0.2
		Rock cover	0.27	0.16	0.05, 0.50
		Canopy cover	-0.74	0.19	-1.02, -0.46
	Occupancy	Intercept	-0.97	0.24	-1.32, -0.63
		Elevation	0.40	0.24	0.06, 0.74
		Herbaceous cover	-0.56	0.23	-0.89, -0.23
m02	Detection	Intercept	-1.40	0.22	-1.72, -1.09
		Max. daily temperature	-0.60	0.22	-0.92, -0.28
		Rock cover	0.24	0.16	0.01, 0.47
		Canopy cover	-0.72	0.20	-1.00, -0.43
	Occupancy	Intercept	-1.12	0.26	-1.50, -0.74
		Visual obstruction	0.48	0.27	0.09, 0.88
		Herbaceous cover	-0.83	0.29	-1.26, -0.41
		Shrub cover	-0.84	0.35	-1.34, -0.33
		Mixed understory cover*	-0.24	0.28	-0.64, 0.16
m37	Detection	Intercept	-1.39	0.22	-1.70, -1.08
		Max. daily temperature	-0.54	0.22	-0.87, -0.22
		Rock cover	0.23	0.16	0.00, 0.46
		Canopy cover	-0.72	0.20	-1.00, -0.43

Model	Submodel	Variable name	β	SE	85% CI
	Occupancy	Intercept	-1.15	0.27	-1.53, -0.76
		Elevation*	0.36	0.26	-0.01, 0.73
		Visual obstruction	0.54	0.28	0.13, 0.94
		Herbaceous cover	-0.86	0.29	-1.28, -0.45
		Shrub cover	-0.74	0.35	-1.25, -0.23
		Mixed understory cover*	-0.24	0.27	-0.64, 0.15
m20	Detection	Intercept	-1.37	0.21	-1.68, -1.06
		Max. daily temperature	-0.59	0.22	-0.91, -0.27
		Rock cover*	0.21	0.16	-0.02, 0.45
		Canopy cover	-0.71	0.20	-1.00, -0.42
	Occupancy	Intercept	-1.17	0.26	-1.55, -0.79
		Dead tree count*	-0.33	0.27	-0.72, 0.07
		Visual obstruction	0.49	0.27	0.10, 0.88
		Herbaceous cover	-0.89	0.30	-1.32, -0.46
		Shrub cover	-0.79	0.35	-1.29, -0.29
		Mixed understory cover*	-0.24	0.28	-0.65, 0.17
m25	Detection	Intercept	-1.39	0.21	-1.70, -1.08
		Max. daily temperature	-0.60	0.22	-0.92, -0.29
		Rock cover	0.23	0.16	0.01, 0.46
		Canopy cover	-0.73	0.20	-1.01, -0.45
	Occupancy	Intercept	-1.02	0.24	-1.36, -0.68
		Dead tree count*	-0.36	0.26	-0.74, 0.02
		Herbaceous cover	-0.58	0.23	-0.92, -0.24
m05	Detection	Intercept	-1.43	0.21	-1.73, -1.12
		Max. daily temperature	-0.64	0.22	-0.95, -0.32
		Rock cover	0.26	0.15	0.04, 0.48
		Canopy cover	-0.74	0.19	-1.02, -0.46
	Occupancy	Intercept	-0.95	0.23	-1.29, -0.62
		Herbaceous cover	-0.50	0.22	-0.82, -0.17
m31	Detection	Intercept	-1.48	0.22	-1.8, -1.17
		Max. daily temperature	-0.54	0.22	-0.85, -0.22
		Rock cover	0.27	0.16	0.04, 0.50
		Canopy cover	-0.79	0.20	-1.08, -0.50
	Occupancy	Intercept	-1.19	0.27	-1.59, -0.8
		Engelmann spruce dominant	0.95	0.63	0.04, 1.86
		Herbaceous cover	-0.66	0.26	-1.04, -0.28
		Shrub cover	-0.51	0.31	-0.96, -0.07
		Mixed understory cover*	-0.27	0.28	-0.66, 0.13
m73	Detection	Intercept	-1.46	0.22	-1.78, -1.14
		Max. daily temperature	-0.56	0.22	-0.88, -0.24
		Rock cover	0.26	0.16	0.03, 0.49

Model	Submodel	Variable name	β	SE	85% CI
		Canopy cover	-0.78	0.20	-1.07, -0.50
	Occupancy	Intercept	-1.09	0.25	-1.45, -0.74
		Engelmann spruce dominant*	0.88	0.65	-0.05, 1.82
		Dead tree count*	-0.26	0.27	-0.64, 0.12
		Herbaceous cover	-0.55	0.24	-0.9, -0.21

Table S13. Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null occupancy models describing landscape scale habitat selection (model GFC SSOM) of the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range, 2019. "X" indicates that the variable was included in the model. For variable descriptions see Table 4.

	Detection			Occupancy								
Model	Max. daily temp	Rock cover	Canopy cover	Herbaceous cover	Engelmann spruce forest	Boulder height	Montane shrub cover	Montane shrub cover ^2	Gooseberry currant cover	df	ΔAICc	AICc weight
m15	x	x	x	x		x	x	x		9	0.00	0.35
m31	x	x	x	x	x	x	x	x		10	1.05	0.20
m29	x	x	x	x		x	x	x	x	10	1.42	0.17
m31	x	x	x	x	x	x	x	x	x	11	1.71	0.15
m01	x	x	x							5	22.93	0.00

Table S14. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for competitive (AICc delta < 2) models describing landscape scale selection (model GFC SSOM) by the gray-footed chipmunk (GFC) in the contemporary Peñasco least chipmunk range, 2019. *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 4.

Model	Submodel	Variable name	β	SE	85% CI
m15	Detection	Intercept	-1.34	0.22	-1.66, -1.03
		Max. daily temperature	-0.52	0.22	-0.84, -0.21
		Rock cover*	0.20	0.16	-0.03, 0.42
		Canopy cover	-0.70	0.19	-0.98, -0.42
	Occupancy	Intercept	-2.46	0.55	-3.26, -1.66
		Herbaceous cover	-0.68	0.27	-1.07, -0.28
		Boulder height	0.67	0.24	0.33, 1.01
		Montane shrub cover	-2.65	0.80	-3.81, -1.49
		Montane shrub cover ^2	1.12	0.49	0.42, 1.82
m31	Detection	Intercept	-1.37	0.22	-1.68, -1.05
		Max. daily temperature	-0.51	0.22	-0.83, -0.19
		Rock cover*	0.20	0.16	-0.02, 0.43
		Canopy cover	-0.73	0.20	-1.01, -0.44
	Occupancy	Intercept	-2.47	0.54	-3.24, -1.70
		Herbaceous cover	-0.66	0.28	-1.06, -0.26
		Engelmann spruce forest*	0.64	0.62	-0.25, 1.54
		Boulder height	0.69	0.24	0.35, 1.04
		Montane shrub cover	-2.48	0.79	-3.61, -1.35
		Montane shrub cover ^2	1.04	0.46	0.39, 1.70
m29	Detection	Intercept	-1.33	0.22	-1.65, -1.02
		Max. daily temperature	-0.53	0.22	-0.85, -0.22
		Rock cover*	0.19	0.16	-0.03, 0.42
		Canopy cover	-0.69	0.19	-0.97, -1.04
	Occupancy	Intercept	-2.50	0.56	-3.31, -1.69
		Herbaceous cover	-0.65	0.27	-1.04, -0.26
		Boulder height	0.63	0.24	0.28, 0.98
		Montane shrub cover	-2.70	0.82	-3.87, -1.53
		Montane shrub cover ^2	1.14	0.49	0.43, 1.86
		Gooseberry currant cover*	-0.23	0.28	-0.64, 0.17
m32	Detection	Intercept	-1.36	0.22	-1.68, -1.04
		Max. daily temperature	-0.51	0.22	-0.83, -0.19
		Rock cover*	0.20	0.16	-0.03, 0.43
		Canopy cover	-0.72	0.20	-1.01, -0.44
	Occupancy	Intercept	-2.54	0.54	-3.31, -1.76
		Herbaceous cover	-0.63	0.28	-1.03, -0.23
		Engelmann spruce forest*	0.90	0.69	-0.09, 1.90
		Boulder height	0.64	0.24	0.29, 0.99
		Montane shrub cover	-2.49	0.79	-3.63, -1.36

Model	Submodel	Variable name	β	SE	85% CI
		Montane shrub cover ^2	1.05	0.46	0.38, 1.71
		Gooseberry currant cover*	-0.36	0.32	-0.82, 0.10

Table S15. Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null multi-species occupancy models describing the landscape scale habitat selection (model MSOM) of Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) in the contemporary PLC range, 2019. "X" indicates that the variable was included in the model. For variable descriptions see Table 5.

	Detection GFC	Detection PLC	Occupancy GFC				Occupancy PLC				Occupancy Both				
Model	Canopy cover	Max. daily temp	Herbaceous cover	Boulder height	Montane shrub cover	Montane shrub cover^2	Elevation	Tree cover	Herbaceous mean	Small-scale edge	Herbaceous cover	Visual obstruction	nPars	ΔAICc	AICc weight
m117	x	x	x	x	x	x	x	x	x	x	x	x	17	0	0.812
m01													7	88.04	0

Table S16. Factor loading for Principal Components Analysis (PCA; first five dimensions) used to describe Peñasco least chipmunk (PLC) microhabitat selection on Nogal Peak, 2018-2023. "-" indicates that a variable was not included in the model. For variable descriptions see Table 6.

	PLC PCA1					PLC PCA2				
Variable name	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Elevation	0.76	0.30	-0.24	-0.14	0.03	0.02	0.86	-0.02	0.31	0.26
Slope	-0.16	-0.05	0.40	0.16	0.48	0.22	-0.44	0.42	-0.30	-0.32
Aspect	-0.32	0.30	0.57	-0.09	-0.28	-	-	-	-	-
bldr.count	0.56	0.49	-0.04	0.13	-0.11	-0.26	0.45	0.25	0.33	-0.42
QUGA.big10	-0.35	0.00	-0.12	0.04	0.10	-0.03	-0.71	-0.33	0.52	-0.11
QUGA.small	-0.65	0.09	-0.11	0.07	0.17	-	-	-	-	-
PIPO.count	-0.10	-0.11	-0.01	-0.04	-0.43	-	-	-	-	-
PIED.count	-0.36	0.09	0.17	0.08	-0.31	-	-	-	-	-
bldr.hght	0.15	0.41	0.16	0.12	-0.01	-	-	-	-	-
visual.obstr	-0.31	0.76	0.00	-0.17	0.15	-0.81	0.22	-0.01	-0.20	0.24
shrub.hght	0.13	0.35	-0.10	0.42	0.28	-	-	-	-	-
shrub.dist	0.41	-0.68	0.18	-0.11	0.18	0.86	0.17	0.24	0.04	-0.06
tree.dist	0.54	0.00	0.12	-0.39	-0.10	0.63	0.43	-0.51	-0.12	0.01
rock.cover	0.46	0.24	0.32	0.29	-0.32	0.03	0.26	0.38	0.09	-0.72
bare.cover	-0.06	-0.42	-0.10	0.51	-0.23	0.02	-0.33	0.69	-0.07	0.43
litter.cover	-0.24	-0.24	-0.67	-0.19	0.04	0.25	-0.69	-0.38	0.42	0.19
forb.cover	-0.17	-0.05	0.42	-0.20	0.35	0.38	0.00	-0.56	-0.53	-0.13
Artemisia.cover	0.47	-0.33	0.13	0.27	0.14	0.28	-0.01	0.59	0.40	0.32
QUGA.cover	-0.19	0.31	-0.04	-0.65	-0.20	-0.63	-0.14	0.07	-0.29	0.08
RONE.cover	0.27	0.36	-0.17	-0.33	0.19	-	-	-	-	-
Holodiscus.cover	0.54	0.30	-0.29	0.22	0.10	-0.23	0.67	-0.24	0.50	0.15
RIMO.cover	0.27	0.28	-0.35	0.03	0.04	-	-	-	-	-
tall.grass.cover	0.28	-0.53	0.26	-0.25	0.33	0.73	0.16	0.11	-0.04	0.31
short.grass.cover	-0.01	-0.26	-0.05	0.05	-0.57	-0.33	-0.11	0.02	-0.60	0.19
shrub.spp.count	-0.18	0.61	0.29	0.26	0.12	-0.91	0.16	-0.08	0.12	-0.03
stump.log.count	-0.50	-0.02	-0.43	0.21	0.18	-0.22	-0.74	-0.11	0.40	-0.07

Table S17. Variables, degrees of freedom (df), Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null logistic regression models describing microhabitat scale habitat selection (model PLC REG) of the Peñasco least chipmunk (PLC) on Nogal Peak, 2018-2023. "X" indicates that the variable was included in the model. For variable descriptions see Table 6.

Model	Holodiscus.cover	Elevation	Aspect	Stump.log.count	df	ΔAICc	AICc weight
m08			x	x	3	0.00	0.14
m09		x	x	x	4	0.86	0.09
m14	x		x	x	4	1.47	0.07
m06		x	x		3	1.86	0.06
m00					1	6.56	0

Table S18. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for competitive (AICc delta < 2) logistic regression models describing microhabitat scale habitat selection (model PLC REG) of the Peñasco least chipmunk (PLC) on Nogal Peak, 2018-2023. *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 6.

Model	Variable name	β	SE	85% CI
m08	Intercept	-2.86	0.56	-3.82, -2.16
	Aspect	-0.78	0.32	-1.26, -0.33
	stump.log.count	-1.23	0.71	-2.45, -0.38
m09	Intercept	-2.88	0.56	-3.83, -2.18
	Elevation*	0.40	0.34	-0.11, 0.89
	Aspect	-0.68	0.33	-1.17, -0.21
	stump.log.count	-1.02	0.71	-2.24, -0.16
m14	Intercept	-2.84	0.56	-3.79, -2.14
	Holodiscus.cover*	0.24	0.29	-0.17, 0.66
	Aspect	-0.64	0.37	-1.17, -0.1
	stump.log.count	-1.11	0.72	-2.35, -0.23
m06	Intercept	-2.6161	0.4509	-3.34, -2.03
	Elevation	0.5971	0.3112	0.14, 1.05
	Aspect	-0.6008	0.3164	-1.07, -0.15

Table S19. Factor loading for Principal Components Analysis (first five dimensions) used to describe gray-footed chipmunk (GFC) microhabitat selection (models GFC PCA1 and GFC PCA2) on Nogal Peak, 2018-2023. For variable descriptions see Table 6.

	GFC PCA1					GFC PCA2				
Variable name	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Elevation	0.76	0.30	-0.24	-0.14	0.03	0.83	0.05	-0.20	-0.06	0.07
Slope	-0.16	-0.05	0.40	0.16	0.48	-0.09	-0.09	0.00	0.55	-0.45
Aspect	-0.32	0.30	0.57	-0.09	-0.28	0.05	0.07	0.64	0.10	-0.37
bldr.count	0.56	0.49	-0.04	0.13	-0.11	0.83	0.08	0.22	0.11	0.05
QUGA.big10	-0.35	0.00	-0.12	0.04	0.10	-0.28	0.18	0.28	0.16	0.13
QUGA.small	-0.65	0.09	-0.11	0.07	0.17	-0.41	0.46	-0.09	0.16	-0.29
PIPO.count	-0.10	-0.11	-0.01	-0.04	-0.43	-0.21	-0.05	0.27	0.03	0.53
PIED.count	-0.36	0.09	0.17	0.08	-0.31	-0.27	0.22	0.53	0.16	0.38
bldr.hght	0.15	0.41	0.16	0.12	-0.01	0.45	0.17	0.45	0.17	-0.09
visual.obstr	-0.31	0.76	0.00	-0.17	0.15	0.10	0.80	-0.08	0.04	-0.17
shrub.hght	0.13	0.35	-0.10	0.42	0.28	0.33	0.19	-0.46	-0.20	-0.30
shrub.dist	0.41	-0.68	0.18	-0.11	0.18	-0.13	-0.74	-0.20	0.33	0.03
tree.dist	0.54	0.00	0.12	-0.39	-0.10	0.67	-0.36	0.16	-0.22	0.11
rock.cover	0.46	0.24	0.32	0.29	-0.32	0.58	-0.35	0.37	-0.08	-0.17
bare.cover	-0.06	-0.42	-0.10	0.51	-0.23	-0.34	-0.28	0.04	-0.57	-0.16
litter.cover	-0.24	-0.24	-0.67	-0.19	0.04	-0.25	0.56	-0.48	0.09	0.18
forb.cover	-0.17	-0.05	0.42	-0.20	0.35	-0.32	-0.08	0.25	0.52	0.24
Artemisia.cover	0.47	-0.33	0.13	0.27	0.14	0.20	-0.53	-0.11	0.25	-0.34
QUGA.cover	-0.19	0.31	-0.04	-0.65	-0.20	-0.07	0.41	0.08	-0.49	-0.15
RONE.cover	0.27	0.36	-0.17	-0.33	0.19	0.49	0.30	-0.23	0.31	0.31
Holodiscus.cover	0.54	0.30	-0.29	0.22	0.10	0.56	0.13	-0.27	0.09	0.16
RIMO.cover	0.27	0.28	-0.35	0.03	0.04	0.43	0.22	-0.26	0.08	0.39
tall.grass.cover	0.28	-0.53	0.26	-0.25	0.33	-0.12	-0.46	-0.43	0.45	-0.01
short.grass.cover	-0.01	-0.26	-0.05	0.05	-0.57	-0.13	-0.36	0.02	-0.34	0.44
shrub.spp.count	-0.18	0.61	0.29	0.26	0.12	0.47	0.45	0.29	0.21	-0.08
stump.log.count	-0.50	-0.02	-0.43	0.21	0.18	-0.48	0.38	0.03	0.11	-0.02

Table S20. Variables, degrees of freedom (df), Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null logistic regression models describing microhabitat scale habitat selection (model GFC REG) of the gray-footed chipmunk (GFC) on Nogal Peak, 2018-2023. "X" indicates that the variable was included in the model. For variable descriptions see Table 6.

Model	visual.obstr	shrub.spp.count	QUGA.big10	QUGA.small	PIED.count	tree.dist	bare.cover	Artemisia.cover	Slope	stump.log.count	forb.cover	df	ΔAICc	AICc weight
m17	x	x		x				x	x	x		7	0.00	0.14
m23	x	x		x	x			x	x	x		8	0.56	0.10
m20	x	x		x			x	x	x	x		8	0.64	0.10
m26	x	x	x	x				x	x	x		8	0.82	0.09
m21	x	x		x		x		x	x	x		8	0.94	0.09
m41	x			x	x			x	x	x		7	1.97	0.05
m19	x	x		x				x	x	x	x	8	1.99	0.05
m00												1	34.56	0.00

Table S21. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for competitive (AICc delta < 2) and null logistic regression models describing microhabitat scale habitat selection of the gray-footed chipmunk on Nogal Peak, 2018-2023. *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 6.

Model	Variable name	β	SE	85% CI
m17	Intercept	-0.07	0.30	-0.51, 0.35
	visual.obstr	0.96	0.44	0.356, 1.63
	shrub.spp.count	0.68	0.34	0.22, 1.19
	Artemisia.cover	-1.02	0.46	-1.73, -0.41
	QUGA.small	0.80	0.33	0.36, 1.30
	Slope	0.71	0.31	0.28, 1.19
	stump.log.count	-1.01	0.41	-1.65, -0.48
m23	Intercept	-0.06	0.30	-0.50, 0.37
	visual.obstr	1.07	0.46	0.44, 1.78
	shrub.spp.count	0.63	0.34	0.16, 1.15
	Artemisia.cover	-0.92	0.46	-1.63, -0.30
	QUGA.small	0.82	0.33	0.37, 1.33
	Slope	0.76	0.33	0.32, 1.27
	PIED.count*	0.46	0.35	-0.03, 0.10
	stump.log.count	-1.12	0.43	-1.80, -0.55
m20	Intercept	-0.04	0.30	-0.48, 0.38
	visual.obstr	0.80	0.44	0.21, 1.48
	shrub.spp.count	0.68	0.34	0.22, 1.19
	bare.cover*	-0.40	0.32	-0.89, 0.03
	Artemisia.cover	-0.98	0.46	-1.69, -0.37
	QUGA.small	0.79	0.33	0.34, 1.29
	Slope	0.70	0.31	0.28, 1.18
	stump.log.count	-0.93	0.41	-1.57, -0.39
m26	Intercept	-0.03	0.30	-0.48, 0.40
	visual.obstr	0.97	0.45	0.36, 1.65
	shrub.spp.count	0.63	0.34	0.17, 1.15
	Artemisia.cover	-0.91	0.45	-1.61, -0.30
	QUGA.small	0.82	0.33	0.36, 1.32
	Slope	0.67	0.31	0.25, 1.15
	stump.log.count	-1.18	0.46	-1.91, -0.58
	QUGA.big10*	0.49	0.44	-0.06, 1.24
m21	Intercept	-0.09	0.30	-0.53, 0.34
	visual.obstr	1.04	0.46	0.41, 1.74
	shrub.spp.count	0.65	0.34	0.18, 1.17
	Artemisia.cover	-0.97	0.45	-1.68, -0.37
	QUGA.small	0.70	0.33	0.24, 1.22
	tree.dist*	-0.33	0.31	-0.89, 0.06
	Slope	0.70	0.32	0.27, 1.19
Model	Variable name	β	SE	85% CI

	stump.log.count	-1.10	0.42	-1.76, -0.54
m41	Intercept	-0.07	0.29	-0.50, 0.34
	visual.obstr	1.29	0.44	0.71, 1.98
	Artemisia.cover	-0.94	0.43	-1.61, -0.36
	QUGA.small	0.85	0.33	0.39, 1.35
	Slope	0.83	0.32	0.40, 1.33
	PIED.count	0.51	0.33	0.06, 1.01
	stump.log.count	-1.26	0.43	-1.93, -0.68
m19	Intercept	-0.07	0.30	-0.51, 0.36
	visual.obstr	1.00	0.44	0.39, 1.66
	shrub.spp.count	0.65	0.34	0.19, 1.17
	Artemisia.cover	-0.97	0.47	-1.69, -0.35
	QUGA.small	0.81	0.33	0.36, 1.31
	Slope	0.67	0.31	0.24, 1.16
	stump.log.count	-0.99	0.41	-1.63, -0.45
	forb.cover*	0.19	0.30	-0.25, 0.64

Table S22. Factor loading for Principal Components Analysis (PCA; first five dimensions) used to describe Peñasco least chipmunk (PLC) and gray-footed chipmunk (GFC) microhabitat selection (model PLC-GFC PCA) on Nogal Peak, 2018-2023. For variable descriptions see Table 6.

	PLC-GFC PCA				
Variable name	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
Elevation	0.85	0.11	-0.21	0.02	0.03
Slope	-0.40	0.02	0.32	-0.10	0.33
Aspect	-0.37	0.57	0.28	0.17	-0.12
bldr.count	0.65	0.42	-0.07	0.13	0.17
QUGA.big10	-0.36	0.16	-0.06	-0.02	0.33
QUGA.small	-0.55	0.18	-0.39	-0.27	0.18
PIPO.count	-0.15	-0.02	-0.08	0.66	0.01
PIED.count	-0.31	0.21	0.15	0.30	0.06
bldr.hght	0.19	0.29	0.26	0.15	0.20
visual.obstr	0.05	0.73	-0.02	-0.31	0.18
shrub.hght	0.20	-0.37	0.27	-0.56	0.01
shrub.dist	0.15	-0.72	-0.07	0.04	0.29
tree.dist	0.84	0.15	0.04	0.14	-0.03
rock.cover	0.57	0.40	0.33	0.17	0.09
bare.cover	-0.09	-0.59	0.29	0.22	0.26
litter.cover	-0.11	-0.24	-0.71	0.00	0.00
forb.cover	-0.33	-0.01	0.49	-0.13	-0.41
Artemisia.cover	0.25	-0.74	0.09	0.00	0.26
QUGA.cover	0.00	0.39	-0.53	-0.03	-0.18
RONE.cover	0.29	0.14	-0.40	-0.20	-0.27
Holodiscus.cover	0.69	-0.08	0.07	-0.13	0.26
tall.grass.cover	-0.06	-0.35	0.15	-0.16	-0.68
short.grass.cover	-0.17	0.08	0.09	0.75	-0.07
shrub.spp.count	-0.01	0.39	0.55	-0.40	0.14
stump.log.count	-0.55	0.16	-0.25	-0.15	0.47

Table S23. Variables, degrees of freedom (df), Variables, degrees of freedom (df), ΔAICc, and AICc weight for competitive (AICc delta < 2) and null logistic regression models comparing microhabitat scale habitat selection (model PLC-GFC REG) of the Peñasco least chipmunk (PLC) with the gray-footed chipmunk (GFC) on Nogal Peak, 2018-2023. "X" indicates that the variable was included in the model. For variable descriptions see Table 6.

Model	Aspect	Elevation	visual.obstr	Holodiscus.cover	QUGA.small	Slope	stump.log.count	Artemisia.cover	shrub.species.count	shrub.dist	bare.cover	df	ΔAICc	AICc weight
m14		x	x									3	0.00	0.09
m16		x	x								x	4	0.46	0.08
m30	x	x	x									4	0.53	0.07
m15	x	x									x	4	1.11	0.05
m24		x	x	x								4	1.33	0.05
m13	x	x										3	1.68	0.04
m22		x	x		x							4	1.78	0.04
m31	x	x					x				x	5	1.92	0.04
m41			x	x								3	1.97	0.04
m20		x	x				x					4	1.97	0.04
m38		x	x			x						4	1.97	0.04
m34		x	x					x				4	1.99	0.04
m00												1	8.55	0.00

Table S24. Standardized parameter estimates (β), standard errors (SE), and 85% confidence intervals (CI) for competitive (AICc delta < 2) logistic regression models comparing microhabitat scale habitat selection (model PLC-GFC REG) of the Peñasco least chipmunk (PLC) with the gray-footed chipmunk (GFC) on Nogal Peak, 2018-2023. *Uninformative variable based on 85% confidence interval. For variable descriptions see Table 6.

Model	Variable name	β	SE	85% CI
m14	Intercept	-2.18	0.49	-2.97, -1.54
	Elevation	1.00	0.39	0.47, 1.62
	visual.obstr	-0.96	0.41	-1.64, -0.43
m16	Intercept	-2.31	0.54	-3.19, -1.62
	Elevation	1.14	0.42	0.58, 1.80
	visual.obstr	-0.79	0.44	-1.5, -0.20
	bare.cover*	0.59	0.43	-0.04, 1.22
m30	Intercept	-2.22	0.50	-3.02, -1.56
	Aspect*	-0.49	0.36	-1.02, 0.04
	Elevation	0.86	0.41	0.28, 1.48
	visual.obstr	-0.78	0.46	-1.53, -0.17
m15	Intercept	-2.21	0.50	-3.03, -1.56
	Aspect	-0.63	0.35	-1.14, -0.12
	Elevation	0.84	0.40	0.27, 1.44
	bare.cover	0.64	0.39	0.09, 1.22
m24	Intercept	-2.23	0.51	-3.05, -1.57
	Elevation	0.78	0.45	0.13, 1.46
	visual.obstr	-1.02	0.42	-1.74, -0.47
	Holodiscus.cover*	0.38	0.38	-0.18, 0.94
m13	Intercept	-2.09	0.47	-2.83, -1.48
	Aspect	-0.76	0.33	-1.24, -0.29
	Elevation	0.63	0.36	0.10, 1.17
m22	Intercept	-2.23	0.51	-3.05, -1.57
	Elevation	0.89	0.42	0.32, 1.54
	visual.obstr	-0.92	0.42	-1.62, -0.37
	QUGA.small*	-0.36	0.52	-1.22, 0.33
m31	Intercept	-2.44	0.63	-3.53, -1.67
	Aspect	-0.70	0.36	-1.25, -0.18
	Elevation*	0.61	0.43	-0.01, 1.26
	stump.log.count*	-0.89	0.80	-2.24, 0.11
	bare.cover	0.63	0.40	0.07, 1.25
m41	Intercept	-2.11	0.47	-2.86, -1.49
	visual.obstr	-0.90	0.37	-1.49, -0.40
	Holodiscus.cover	0.76	0.32	0.30, 1.25
m20	Intercept	-2.24	0.52	-3.09, -1.57
	Elevation	0.88	0.43	0.30, 1.56
	visual.obstr	-0.92	0.42	-1.62, -0.37
Model	Variable name	β	SE	85% CI

	stump.log.count*	-0.36	0.65	-1.44, 0.49
m38	Intercept	-2.17	0.49	-2.95, -1.53
	Elevation	0.86	0.45	0.23, 1.56
	visual.obstr	-0.94	0.41	-1.62, -0.41
	Slope*	-0.24	0.42	-0.88, 0.35
m34	Intercept	-2.17	0.49	-2.96, -1.53
	Elevation	0.96	0.39	0.43, 1.58
	visual.obstr	-0.90	0.44	-1.61, -0.31
	Artemisia.cover*	0.27	0.53	-0.36, 1.14

Appendix

Discrimination of PLC and GFC based on morphology in photographs

Methods

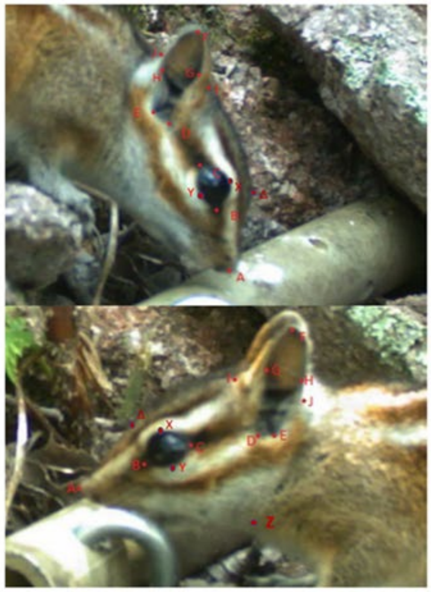
We measured the distance between a series of morphological landmarks on remote camera photographs of chipmunks with the objective of determining whether these measurements can be used to reliably differentiate between photos of Peñasco least chipmunks (*Neotamias minimus atristriatus,* hereafter PLC) and gray-footed chipmunks (*N. canipes*, hereafter GFC). We used photographs of 39 PLC and 39 GFC taken during a recent field study (McKibben & Frey, 2025). These photos were taken at camera sites in the Sierra Blanca subrange of the Sacramento Mountains and were unambiguously identified to species using the methods developed in McKibben and Frey (2021).

We first separated the photos into three profile categories based on the head position of the chipmunk in the image (Figure 1-3). For the perfect head profile (defined as a profile in which one eye, one ear, and the tip of the nose are visible but not the back of head), we included 14 landmarks and 25 measurements (Figure 1). For the profile with the top of the head, in which one eye, both ears, and the top of the head are visible, we included 14 landmarks and 19 measurements (Figure 2). For the profile with the back of the head, in which one eye, one ear, and the back of the head are visible, we included 14 landmarks and 25 measurements (Figure 3). We omitted the measurement for any profile photo in which the landmark was not visible.

We used two different computer screen-based measuring programs to take measurements: SmallMeasure (Lin, 2010) and ImageJ (Schneider et al., 2012). These programs function by using the computer mouse to select the landmarks between which you want the distance. Because the photographs are taken from different distances to the animal and the size of the photo can vary based on the size of the computer screen monitor, we converted the raw measurements into ratios for analysis. The ratios correct for the variation in the size of the chipmunk in the image and/or the size of the image on the screen. To evaluate intra-observer variation in taking the measurements with each tool, we had the same lab technician repeat the measurements on the 39 photographs of each species chipmunk using both software programs.

Profile: One eye and one ear visible. Tip of nose visible. Back of head not visible. Top of head not visible

Landmarks	
Tip of nose	A
Front of eye	B
Back of eye	C
Front ear notch	D
Back ear notch	E
Tip of ear	F
Front of ear at widest point	G
Back of ear at widest point	H
Front of ear at top of head	I
Back of ear at top of head	J
Top of eye	X
Bottom of eye	Y
Bottom of lower mandible	Z
Point of angular change on forehead (stop)	Δ



Measurement	**Description**
AD	Dist. from tip of nose to front ear notch
CE	Dist. from back of eye to back ear notch
BE	Dist. from front of eye to back ear notch
AE	Dist. from tip of nose to back ear notch
DF	Dist. from front ear notch to tip of ear
EF	Dist. from back ear notch to tip of ear
DFE	Dist. from front ear notch to tip of ear + tip of ear to back ear notch
GH	Ear Width (from widest points on front and back)
GF	Dist. from front of ear at widest point to tip
HF	Dist. from back of ear at widest point to tip
GFH	Dist. from front of ear at widest point to tip + dist. from tip of ear to back of ear at widest point
XY	Dist. from top of eye to bottom of eye
AΔ	Dist. from tip of nose to stop
ΔI	Dist. from stop to front of ear at top of head
CD	Dist. from back of eye to front ear notch
BD	Dist. from front of eye to front ear notch
IF	Dist. from front of ear at top of head to tip of ear
JF	Dist. from back of ear at top of head to tip of ear
IJF	Dist. from front of ear at top of head to back of ear at top of head + dist. from back of ear at top of head to tip of ear
AI	Dist. from tip of nose to front of ear at top of head
IAE	Dist. from front of ear at top of head to tip of nose + tip of nose to back ear notch
FAE	Tip of ear to tip of nose + tip of nose to back ear notch
ZI	Depth of head in line from front of ear at top of head
ZD	Bottom of lower mandible to front ear notch
ZE	Bottom of lower mandible to back ear notch

Figure 1. Perfect profile description, landmarks, and measurements for morphometric chipmunk identification analysis.

Profile with top: Top of head and both ears visible. Only one eye visible

Landmarks	
Tip of nose	A
Front of eye	B
Back of eye	C
Front ear notch	D
Back ear notch	E
Tip of ear	F
Front of ear at widest point	G
Back of ear at widest point	H
Tip of back ear	K
Front of back ear where it meets head	L
Back of back ear where it meets head	M
Top of eye	X
Bottom of eye	Y
Point of angular change on forehead (stop)	Δ

Measurement	Description
AD	Dist. from tip of nose to front ear notch
CE	Dist. from back of eye to back ear notch
BE	Dist. from front of eye to back ear notch
AE	Dist. from tip of nose to back ear notch
DF	Dist. from front ear notch to tip of ear
EF	Dist. from back ear notch to tip of ear
EFD	Dist. from front ear notch to tip of ear + tip of ear to back ear notch
GH	Ear Width (from widest points on front and back)
GF	Dist. from front of ear at widest point to tip
HF	Dist. from back of ear at widest point to tip
GFH	Dist. from front of ear at widest point to tip + dist. from tip of ear to back of ear at widest point
XY	Dist. from top of eye to bottom of eye
AΔ	Dist. from tip of nose to stop
ΔI	Dist. from stop to front of ear at top of head
AB	Dist. from tip of nose to front of eye
AC	Dist. from tip of nose to back of eye
MK	Dist. from back of back eat where it meets head to tip of back ear
LK	Dist. from front of back ear where it meets head to tip of back ear
LKM	Dist. from front of back ear where it meets head to tip of back ear + dist. from tip of back ear to back of back ear where it meets head

Figure 2. Profile with top of head description, landmarks, and measurements for morphometric chipmunk identification analysis.

Profile with back: One eye and one ear visible.

Tip of nose may or may not visible. Back of head visible.

Follow same basic measurements as with profile, omit measurements whose landmark is not visible. Add in landmark Z.

Landmarks	
Tip of nose	A
Front of eye	B
Back of eye	C
Front ear notch	D
Back ear notch	E
Tip of ear	F
Front of ear at widest point	G
Back of ear at widest point	H
Front of ear at top of head	I
Back of ear at top of head	J
Top of eye	X
Bottom of eye	Y
Bottom of lower mandible	Z
Point of angular change on forehead (stop)	Δ

Measurement	Description
AD	Dist. from tip of nose to front ear notch
CE	Dist. from back of eye to back ear notch
BE	Dist. from front of eye to back ear notch
AE	Dist. from tip of nose to back ear notch
DF	Dist. from front ear notch to tip of ear
EF	Dist. from back ear notch to tip of ear
DFE	Dist. from front ear notch to tip of ear + tip of ear to back ear notch
GH	Ear Width (from widest points on front and back)
GF	Dist. from front of ear at widest point to tip
HF	Dist. from back of ear at widest point to tip
GFH	Dist. from front of ear at widest point to tip + dist. from tip of ear to back of ear at widest point
XY	Dist. from top of eye to bottom of eye
AΔ	Dist. from tip of nose to stop
ΔI	Dist. from stop to front of ear at top of head
CD	Dist. from back of eye to front ear notch
BD	Dist. from front of eye to front ear notch
IF	Dist. from front of ear at top of head to tip of ear
JF	Dist. from back of ear at top of head to tip of ear
IJF	Dist. from front of ear at top of head to back of ear at top of head + dist. from back of ear at top of head to tip of ear
AI	Dist. from tip of nose to front of ear at top of head
IAE	Dist. from front of ear at top of head to tip of nose + tip of nose to back ear notch
FAE	Tip of ear to tip of nose + tip of nose to back ear notch
ZI	Depth of head in line from front of ear at top of head
ZD	Bottom of lower mandible to front ear notch
ZE	Bottom of lower mandible to back ear notch

Figure 3. Profile with back of head description, landmarks, and measurements for morphometric chipmunk identification analysis.

Results

We found low intra-observer variation (Table 1) and non-significant differences between the results of analyses performed using SmallMeasure vs. analyses using ImageJ (Table 2). We found several ratios that suggest there are significant morphological differences between the two species of chipmunks (PLC and GFC). Preliminary analysis indicates that PLC have a shorter rostrum (relative to head length) and a shorter ear (relative to multiple measurements between landmarks on the face) than does the GFC. We plan to conduct a formal analysis of all three head profiles and formalize the results to evaluate the validity of using this technique to differentiate between the two chipmunk species.

Table 1. Comparison of means, sample size, standard deviation, and 95% confidence intervals for selected ratios of measurements on two species of chipmunks (PLC and GFC) based on measurement tool.

	ImageJ		SmallMeasure		
Ratio	Mean (N, SD)	95% CI	Mean (N, SD)	95% CI	p
Tip of nose to front of eye: Tip of nose to front of ear notch	0.41 (69, 0.06)	(0.40-0.43)	0.42 (68, 0.07)	(0.40-0.44)	0.427
Back of eye to front ear notch: Back of ear notch to tip of ear	0.74 (101, 0.15)	(0.71-0.77)	0.74 (96, 0.14)	(0.71-0.76)	0.704
Back of ear notch to tip of ear: Tip of nose to front of ear notch	0.53 (73, 0.11)	(0.51-0.56)	0.55 (68, 0.10)	(0.53-0.58)	0.308

Table 2. Comparison of means, sample size, standard deviation, and 95% confidence intervals for selected ratios of measurements between two species of chipmunks.

	ImageJ		SmallMeasure		
Ratio	Mean (N, SD)	95% CI	Mean (N, SD)	95% CI	p
Tip of nose to front of eye: Tip of nose to front of ear notch	0.45 (46, 0.05)	(0.44-0.47)	0.39 (91, 0.06)	(0.38-0.41)	<0.001
Back of eye to front ear notch: Back of ear notch to tip of ear	0.64 (81, 0.14)	(0.61-0.67)	0.81 (115, 0.10)	(0.79-0.83)	<0.001
Back of ear notch to tip of ear: Tip of nose to front of ear notch	0.61 (46, 0.10)	(0.58-0.63)	0.51 (95, 0.09)	(0.49-0.53)	<0.001

Literature Cited

Lin, M. (2010). *SmallMeasure* (Version 1.0) [Computer software]. https://www.softpedia.com/get/Desktop-Enhancements/Other-Desktop-Enhancements/SmallMeasure.shtml

Schneider, C. A., Rasband, W. S., & Eliceiri, K. W. (2012). NIH Image to ImageJ: 25 years of image analysis. *Nature Methods*, *9*(7), 671–675. https://doi.org/10.1038/nmeth.2089