Interim Project Report for Share with Wildlife

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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INTRODUCTION

The Peñasco least chipmunk (*Neotamias minimus atristriatus*; hereafter, PLC) is endemic to the Sacramento Mountains in southern New Mexico, USA (Bailey 1913, Conley 1970, Sullivan 1985, Sullivan and Petersen 1988). The PLC is listed as endangered by the state of New Mexico (NMDGF 2016) and is proposed for federal listing as an endangered species (USFWS 2021). The PLC is currently considered to be extirpated from much of its historical range, including the southern Sacramento subrange in the Lincoln National Forest (Hope and Frey 2000, Frey and Boykin 2007, Frey and Hays 2017). In the northern Sierra Blanca subrange, the chipmunk persists in two known populations occurring on Lookout Mountain and Nogal Peak (McKibben 2022). For the purposes of our study, we refer to these two locations and the intervening high elevation areas of the Sierra Blanca subrange in the Lincoln National Forest as the subspecies' contemporary range.

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 montegenum*). Lookout Mountain is the largest remaining patch of this vegetation type on public land in the Sacramento Mountains. Formerly, similar Engelmann spruce forests were widespread across the upper elevations of the Sierra Blanca subrange. Recent research estimates that the Lookout Mountain population is composed of approximately 44 individuals occupying approximately 15 hectares of habitat (McKibben et al. 2021, McKibben 2022).

The habitat occupied by the population at Nogal Peak is a Gambel oak (*Quercus gambelii*) shrubland characterized by dense shrubs interspersed with occasional large-diameter 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 may represent an example of this process. The presence of PLC in the Gambel oak disclimax vegetation community on Nogal Peak is important because it suggests that other populations of the PLC could exist, as there are other areas of Gambel oak disclimax in the Sacramento Mountains; it also suggests that the PLC may have the behavioral plasticity necessary to persist in wildfire-transformed vegetation communities. The existence of the PLC population at Nogal Peak was first documented in 2018 (McKibben 2022) and is known from four live-trap detection locations and one camera-trap detection location.

The persistence of the PLC is threatened by habitat alteration, drought, wildfire, and potential competition with the gray-footed chipmunk (*Neotamias canipes*; hereafter, GFC; NMDGF 2016). The GFC, a larger and more arboreal chipmunk, is sympatric with the PLC across the entirety of the PLC's range (Best et al. 1992). When sympatric with other chipmunk species, least chipmunks are often displaced by larger and more aggressive congeners (Chappell 1978, Poffenroth and Matson 2007, Root et al. 2001). Across much of its historical range, the PLC has been replaced by the GFC (NMDGF 2016, Frey and Boykin 2007), lending anecdotal support to the hypothesis that interspecies competition with the GFC is contributing to the decline of the PLC.

The potential for interspecies competition exists when two species share the use of limited environmental resources. Interspecies competition can take the form of exploitative interactions (i.e., one species consumes the shared resource and thus makes it unavailable to 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 distributions is difficult in the absence of manipulative experiments, but we propose a framework where a comparison between habitat selection at multiple scales will identify the overlap of habitat preferences between the chipmunk species. This overlap highlights the shared resources and thus is the most likely source of any ongoing competition between the species. Alternatively, if there is no overlap of preferred habitat, then the species might have co-evolved to avoid competition altogether or there could be intense competition resulting in the complete exclusion of the inferior competitor. Our approach will not definitively distinguish between these possibilities; however, if the habitat preference of one species varies depending on the presence or absence of the other species, then that resource is potentially a shared habitat preference that is subject to competition between the species.

The overall goal of this study is to better understand the habitat of the PLC and the potential for competitive interaction with the GFC. We aim to understand the distribution and microhabitat selection of the PLC in the post-fire, disclimax vegetation community at Nogal Peak. Additionally, we aim to understand the potential for competition between the PLC and the GFC at the landscape and microhabitat scales. The objectives are to: 1) Evaluate microhabitat selection of the PLC in a post-fire disclimax oak shrubland on Nogal Peak and compare with microhabitat selection in unburnt, subalpine coniferous forest on Lookout Mountain, 2) Evaluate habitat selection of the GFC (a potential competitor of the PLC) where the chipmunk species' ranges overlap and explicitly test the hypothesis that presence of GFC limits the occupancy of PLC, 3) Continue monitoring the PLC population on Lookout Mountain via motion-activated cameras, 4) Learn about the timing of PLC hibernation, and 5) Determine whether morphological features measured in photographs of chipmunks can be used to differentiate between the species. Results of this study will address key information gaps necessary to develop scientifically defensible conservation and management plans for the PLC and will provide crucial information necessary to understand how this subspecies might be able to persist in ecosystems transformed by fire.

METHODS

Project modifications and tasks

There have been five major modifications to the original study design. 1) In 2022, the start of field work was delayed due to wildfire closures. During that down-time, we began a pilot study to determine if measurements taken on photos could be used to differentiate between the two chipmunk species. A formal analysis of the morphology data was added as a new task. 2) Because PLC are less abundant at Nogal Peak than originally believed, the study design was changed from occupancy modeling to use-versus-available, allowing us to target surveys in locations where detection of chipmunks was more likely and then compare used sites to representative comparative locations. 3) A new task was added to evaluate habitat selection of the GFC at landscape scale and test for competition with the PLC. 4) The original graduate student assigned to this project resigned and was replaced; consequently, the overall project duration was extended. 5) Based on preliminary analysis of data collected during 2022, we determined that there would be an insufficient number of detections to meet the original objective of estimating the abundance and reproduction of the PLC on Nogal Peak, so this task was deleted. 6) A new task was added to estimate the timing of hibernation emergence by the

PLC on Nogal Peak. These changes were communicated with the Share with Wildlife staff in detail and approved in Amendment 1.

These changes resulted in five tasks to be completed: 1) Survey Nogal Peak and evaluate PLC microhabitat selection with a used-versus-available analysis, 2) Evaluate habitat selection of GFC using occupancy modeling and test for potential competition with PLC, 3) Deploy cameras over the 2023/2024 winter to capture timing of hibernation, 4) Continue monitoring the PLC population on Lookout Mountain, and 5) Conduct formal analysis of morphology data to evaluate the efficacy of using morphometric data to identify chipmunk species.

Task 1: Distribution and microhabitat selection of PLC at Nogal Peak

Chipmunk surveys. We surveyed chipmunks using motion-triggered cameras following the methods developed in McKibben and Frey (2021). Cameras have been demonstrated to be an effective survey method for PLC as well as for other chipmunk species (Perkins-Taylor and Frey 2018, McKibben 2022, Jacobson 2023, Schweiger and Frey 2021). We mounted the cameras on PVC tripods with the camera pointed down, positioned approximately 1 m from a peanut butter scent lure. According to McKibben (2022), the minimum number of days necessary to achieve a 90% likelihood of at least one PLC detection where it is present varied depending on daily maximum temperature, precipitation, and the age of the scent lure; however, nine days was the maximum required under any weather conditions. We deployed cameras at a site for a minimum of ten days to ensure that we achieved at least a 90% likelihood of detecting a PLC, if present, under any weather conditions.

Our survey effort was initially concentrated at or near sites where PLC have been historically documented to occur. We surveyed these areas intensely, placing cameras approximately 40 m apart. We then expanded across the study area, placing cameras approximately 80 m apart to survey as much of Nogal Peak as possible. To maximize the probability of detection, the final camera placement was within best available microhabitat at the site, rather than setting cameras at strict spacing intervals. When possible, cameras were set in areas with microhabitat features known to be used by PLC (i.e., where herbs and shrubs provided visual obstruction near the edges between cover and grass, and in the vicinity of large-diameter trees if possible [McKibben 2022]).

Variable data collection. We collected site characteristic data at used and available sites. We considered a site to be "used" if there was at least one PLC detected at that location. We considered a site to be "available" if no chipmunk was detected or if the site was randomly generated. Random sites were determined using a random number generator to produce a random bearing and random distance between 20-160 m from the center of a used site. This range of distances was chosen because 20 m minimum distance prevented the used and random sampling plots from overlapping and 160 m was the distance a chipmunk might travel to find resources at the home range scale (McKibben 2022). Any random point falling outside of the study area boundaries or in terrain deemed unsafe for the field crew to access was rejected and regenerated.

At both used and available sites, we collected data along four, equally spaced 10-m transects using a random number generator to select the azimuth of the first transect originating from the site. We measured canopy cover using a spherical densiometer standing at the site and facing in each cardinal direction (Forest Densiometers - Model A (convex) #102165). To estimate the amount of vertical cover, we used a 1-m long x 2.6-cm diameter cover pole marked with alternating-colored bands at 10-cm increments (Griffith and Youtie 1988) to take three readings along each of the four transects (center to 5 m, 5 m to center, 10 m to 5 m). The pole was read with eye level at 1 m and a band was "covered" if more than 25% of the band was concealed from view. We used a 20 x 50 cm quadrat (Daubenmire 1959) that was read from a height of 1 m to estimate the percentage of ground cover. Readings were taken at the 2, 4, 6, and 8 meter marks along each transect. Ground cover type (Table 1) was recorded and classified into coverage categories (0-5%, 5-25%, 25-50%, 50-75%, 75-95%, 95-100%). Along each transect, we identified every tree (> 2 m tall with a trunk at least 5 cm in diameter at breast height) within 1 m to species. Within 1 m of each transect, we measured tree diameter at breast height and tallied the number of trees by diameter class (5-10 cm, 10-20 cm, 20-30 cm, 40-50 cm, > 50 cm); we also counted the number of boulders (any dimension > 0.5 m), logs (> 10 cm diameter) and stumps (dead, rooted tree < 2 m tall with a trunk of at least 5 cm in diameter at breast height). Using a Nikon Aculon laser range finder, we measured the distance from the center of the survey site to the nearest shrub and the nearest tree, identifying each of those individuals to species. We also recorded the height and species of the tallest shrub and the height of the tallest boulder, stump, and log within a 10 m radius of the center of the survey site. Weather data were collected at each used site for the duration of the camera deployment period by using a Hygrocron Temperature and Humidity Data Logger (Model DS1923-F5#) set to record temperature and humidity every 30 minutes.

Chipmunk identification. Because the PLC and GFC are morphologically similar, we followed the stringent recommendations of McKibben and Frey (2021) to ensure that chipmunks were unambiguously identified to species. We relied on trained observers who identified the chipmunks based on pelage characteristics and only considered photos as unambiguous detections if two observers agreed on the species identification with high confidence. Photos identified as PLC were subject to expert review by Jennifer Frey, Fiona McKibben, and William Grooms. Any chipmunk photo that lacked agreement on species or that was identified with low confidence was considered ambiguous and removed from further analysis.

Table 1. Ground cover classes measured with a 20 cm x 50 cm Daubenmire frame along four 10 m transects at used and available sites during surveys for PLC on Nogal Peak in the White Mountain Wilderness Area of the Lincoln National Forest, NM, USA, 2022-2023.

Ground cover type classifications
Ribes montigenum
Ribes pinetrorum
Ribes wolfi
Ribes cereum
Lupinus sp.
Archillea millefolium
Iris missouriensis
Urtica gracilenta
Unknown shrub
Unknown forb
Short grass (< 20 cm)
Tall grass (> 20 cm)
Picea engelmannii
Pseudotsuga menziesii
Abies lasiocarpa
Quercus gambelii
Artemesia sp.
Holodiscus dumosus.
Robinia neomexicana
Deciduous
Dead tree
Log (> 10-cm diameter)
Bare ground
Litter
Rock (10-50 cm)
Boulder (50 cm - 5 m)
Bedrock (> 5 m)
Pinecone
Presence of ungulate feces
Presence of vole runway
Presence of gopher mound
Presence of lagomorph feces

Task 2: Landscape-scale habitat selection of GFC

Data collection. We leveraged an existing dataset collected as part of a prior occupancy study on the PLC to evaluate the landscape-scale habitat selection of the GFC and to test the hypothesis that competition with GFC influences the occupancy of PLC. This dataset was previously analyzed to explicitly test five hypotheses thought to determine first order (landscape scale) habitat selection of the PLC based on five categories of environmental factors: biotic community type, topography, disturbance, edge, and understory structure (McKibben 2022). Based on the results of McKibben (2022), the occupancy probability of PLC in the contemporary range is positively associated with increased elevation, increased visual obstruction, and increased tree count when herbaceous cover is also high. These data were collected June – October 2019 using motion activated cameras at elevations > 2,500 m in the Sierra Blanca sub-range in two survey periods. During the first survey period (02 June 2019 – 01 August 2019), sites were stratified by elevation and vegetation type, then randomly distributed in the strata. During the second survey period (08 August 2019 – 07 October 2019), core PLC habitat was targeted for random placement of cameras.

The dataset is comprised of presence/absence data collected across 1,184 24-hour survey periods at 238 sites. PLC were detected during 46 surveys at 27 sites and GFC were detected during 153 surveys at 49 sites (Table 2). We created a detection history based on the unambiguously identified photos of GFC in the McKibben (2022) dataset. Also contained in the dataset are variable data used to test hypotheses about factors influencing detection and occupancy of the PLC.

Because we are testing the same variables and using data collected at the same time, following the same methods and under the same conditions to model GFC occupancy as was previously used to model PLC occupancy, the results of our GFC occupancy model will be directly comparable to the results of the previous PLC occupancy model (McKibben 2022). Using the data collected to model PLC occupancy will also limit the scope of our inferences to be narrowly focused on GFC occupancy within the contemporary PLC range and not on GFC occupancy in general. We will interpret the occupancy probability as habitat preference and compare the habitat preferences of GFC with PLC to identify potential sources of competition between the chipmunks.

Table 2. Summary of surveys for PLC conducted June – October 2019 in the Sierra Blanca subrange, Lincoln National Forest, NM, USA (McKibben 2022).

Presence/absence	Surveys	Sites
Total	1,184	238
PLC detections	46	27
GFC detections	153	49

Statistical methods. We used an information theoretic approach (Andersen et al. 2000) to create *a priori* models based on the literature and firsthand knowledge of the GFC in the study area. We tested a set of six variables for detection (Table 3) and 14 variables for occupancy (Table 4). Each *a priori* model represented an individual hypothesis meant to explain factors influencing detection or occupancy of the GFC. We assessed relative model fit using AICc (Burnham and Andersen 2002). All models ≤ Δ 2 AICc were considered competitive. We excluded any models with uninformative parameters (Arnold 2010) following the methods of Leroux (2019). We averaged across all competitive models and reported the averaged models as the top model. We will assess the top model for multicollinearity between predictor variables by calculating the variance inflation factor (O'Brien 2007) and for goodness-of-fit by using Dunn-Smyth residual plots (Warton et al. 2017). All analyses were run in the unmarked (Fiske and Chandler 2011) and MuMIn (Barton 2023) packages in R (R Foundation for Statistical Computing, Vienna, Austria).

GFC detection model. We hypothesized that GFC detection would be influenced by maximum daily temperature, precipitation, scent lure age, survey period, rock cover and forest cover (Table 3). Chipmunks are more active on cooler days (Schweiger and Frey 2021) and on days when it rains (McKibben 2022); therefore, we predicted that detection probability would decrease as maximum daily temperature increased and would increase on days when it rained. As the bait inside of the scent lure tube ages its effectiveness decreases; therefore, we predicted that detection probability will decrease as the age of the scent lure increased. Because different habitat conditions were surveyed during the two survey periods, which can influence GFC abundance, we predicted that detection probability would differ between the survey periods. Environmental conditions associated with occupancy can also influence detection probability (Efford and Dawson 2012) due to an increase in abundance when those conditions are present. GFC are more abundant in areas with greater rock cover and in live coniferous forests which characteristically form dense canopy covers (Best 1992); therefore, we predicted that detection probability would increase as the amount of rock and canopy cover increased at the site. Because GFC detection in the contemporary PLC range is unstudied and *a priori* knowledge is limited, we tested all possible combinations of these variables.

Table 3. Variables, descriptions and predicted effects for variables used to model detection probabilities for GFC in the Sierra Blanca subrange of the Sacramento Mountains, NM, USA.

Variable	Description	Predicted effect
Maximum temperature	Maximum temperature at each site on survey date; recorded on iButton	- as max. temp increases
Precipitation	Categorical indicating if it rained on survey date; recorded at Sierra Blanca weather station	+ on days when it rains
Scent lure age	Number of days since scent lure was deployed	- as age increases
Survey period	Categorical indicating in which survey period the survey occurred	+ during period 2
Rock cover	Mean % rock, boulder and bedrock cover at site; measured in Daubenmire frames	+ as rock cover increases
Forest cover	Mean canopy cover at site; measured on densiometer	+ as canopy cover increases

GFC occupancy models. To test the hypothesis that interspecies competition for habitat resources potentially exists between PLC and GFC, we will model GFC occupancy in the PLC's current range using habitat variables known or hypothesized to influence PLC occupancy. The probability of occupancy for the PLC increased with increasing elevation and percent visual obstruction, and with an interaction effect that described increasing occupancy probability with increased tree cover when herbaceous cover was also high (McKibben 2022). Variables not in the top model that were also hypothesized to influence PLC occupancy probability were vegetation community type, dead tree count, ecotone, sub-alpine edge, small-scale edge, shrub cover, herbaceous cover and mixed understory cover. If competition exists between the chipmunks, we predict that the occupancy probability of GFC will overlap with that of the PLC in one or more of these variables.

For our first GFC occupancy model, we narrowed the focus of our comparison to include only the three occupancy variables in McKibben's top PLC occupancy model (Table 4). The occupancy probability for PLC increased with increasing elevation, increasing percent visual cover and increased small-scale edge (i.e., an interaction between tree cover and herbaceous cover; McKibben 2022). By modeling GFC occupancy with these same variables, we will highlight the resources where direct competition between the chipmunks is most likely.

For our second GFC occupancy model, we expanded the scope of our comparison to include all 14 variables that were hypothesized to influence PLC occupancy (Table 4) and tested 128 *a priori* occupancy sub-models using the top detection variables from our GFC detection model (Table 5.). For both models, we interpret occupancy probability as GFC habitat selection preference within the contemporary PLC range.

Table 4. Variables and descriptions by model for variables used to model occupancy probabilities for GFC in the Sierra Blanca subrange of the Sacramento Mountains, NM, USA.

Sub-model	Variable	Description
GFC occupancy based on three known PLC occupancy variables	Elevation	Mean elevation at site; GIS variable at 10 m spatial resolution
	Visual obstruction	Mean % of bands on cover pole that were at least 25% obstructed
	Small-scale edge	Interaction between tree count along belt transects and mean % herbaceous cover
GFC occupancy based on additional hypothesized PLC occupancy variables	Community	Categorical with five community types (dead, montane, corkbark fir dominant, Engelmann spruce dominant, 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 area with no trees
	Dead tree count	Count of dead trees; measured along belt transects
	Ecotone	Categorical indicating presence / absence in 80 m wide contiguous coniferous and herbaceous cover
	Subalpine edge	Interaction between subalpine cover and herbaceous cover in 80 m radius; GIS variable
	Shrub cover	Mean % shrub cover
	Herbaceous cover	Mean % herbaceous cover
	Mixed understory cover	Interaction between mean % herbaceous cover and shrub cover

Table 5. List of *a priori* occupancy sub-models used to model occupancy probabilities for GFC in the Sierra Blanca subrange of the Sacramento Mountains, NM, USA. “x” indicates that the variable was included in that model.

Model	Community	Montane	Corkbark fir dominant	Engelmann spruce dominant	Open	Elevation	Dead tree count	Ecotone	Subalpine edge	Small-scale edge	Visual obstruction	Shrub cover	Herbaceous cover	Mixed understory cover
1														
2											x			x
3											x			
4														x
5													x	
6							x			x				
7										x				
8							x							
9	x													
10		x	x	x	x									
11		x		x										
12				x										
13		x	x											
14		x	x		x									
15						x								
16								x						
17									x					
18							x			x	x			x
19										x	x			x
20							x				x			x
21							x			x	x			
22										x	x			
23							x				x			
24							x							x
25							x						x	
26	x										x			
27	x													x
28				x							x			x
29				x							x			
30				x	x						x			
31				x										x
32				x									x	

Model	Community	Montane	Corkbark fir dominant	Engelmann spruce dominant	Open	Elevation	Dead tree count	Ecotone	Subalpine edge	Small-scale edge	Visual obstruction	Shrub cover	Herbaceous cover	Mixed understory cover
33		x		x							x			
34		x	x								x			x
35		x	x		x						x			
36		x												x
37						x					x			x
38						x					x			
39						x								x
40						x							x	
41								x			x			x
42								x			x			
43								x						x
44								x					x	
45									x		x			
46									x					x
47									x		x			x
48	x									x				
49				x						x				
50				x			x			x				
51		x	x				x			x				
52		x	x		x		x							
53						x	x			x				
54						x				x				
55						x	x							
56							x	x		x				
57								x		x				
58							x	x						
59							x		x					
60					x	x								
61				x				x						
62		x	x					x						
63		x		x				x						
64	x							x						
65	x									x	x			x
66	x									x	x			
67				x						x	x			x

Model	Community	Montane	Corkbark fir dominant	Engelmann spruce dominant	Open	Elevation	Dead tree count	Ecotone	Subalpine edge	Small-scale edge	Visual obstruction	Shrub cover	Herbaceous cover	Mixed understory cover
68				x						x	x			
69				x						x				x
70		x		x						x	x			x
71		x		x						x	x			
72		x	x							x	x			
73				x			x						x	
74		x	x				x						x	
75					x		x				x			
76		x		x			x			x	x			
77				x			x			x	x			
78						x	x			x	x			x
79						x				x	x			x
80						x	x				x			x
81						x	x			x	x			
82						x				x	x			
83						x	x				x			
84						x	x							x
85						x	x						x	
86							x	x		x	x			x
87								x		x	x			x
88							x	x			x			x
89							x	x		x	x			
90								x		x	x			
91							x	x			x			
92							x	x						x
93							x	x					x	
94							x		x		x			
95							x		x					x
96							x		x				x	
97					x	x	x			x				
98					x	x				x				
99					x	x	x							
100	x							x		x				
101				x				x		x				
102				x			x	x		x				

Model	Community	Montane	Corkbark fir dominant	Engelmann spruce dominant	Open	Elevation	Dead tree count	Ecotone	Subalpine edge	Small-scale edge	Visual obstruction	Shrub cover	Herbaceous cover	Mixed understory cover
103		x	x				x	x		x				
104		x	x		x		x	x						
105		x					x		x					
106		x	x				x		x					
107					x	x	x				x			
108								x		x	x			x
109								x		x	x			
110				x				x		x	x			x
111				x				x		x	x			
112				x				x		x				x
113		x		x				x		x	x			x
114		x		x				x		x	x			
115		x	x					x		x	x			
116				x			x	x					x	
117		x	x				x	x					x	
118					x		x	x			x			
119		x		x			x	x		x	x			
120				x			x	x		x	x			
121		x	x				x		x		x			
122		x					x		x		x			
123				x			x	x		x	x			x
124				x			x	x		x	x			
125				x			x	x		x				x
126		x		x			x	x		x	x			x
127		x		x			x	x		x	x			
128		x	x				x	x		x	x			

Task 3: PLC hibernation

Chipmunk surveys. We surveyed chipmunks using motion triggered cameras following the methods developed in McKibben and Frey (2021). We mounted the cameras on PVC tripods with the camera pointed down, approximately 1 m from a peanut butter scent lure. We set cameras at eight sites where PLC have been detected (Appendix 2), including five sites with recent detections in 2022-2023 and three sites with historical detections in 2018-2019 (McKibben 2022). Six of these cameras were already in place on 1 October 2023 to gather data for the microhabitat study and were visited during the month of September 2023 to refresh the batteries and deploy new SD cards. In early October 2023, two additional potential PLC detection sites were identified; cameras were deployed at these sites on 7 October 2023. All cameras were visited on 29 or 30 December 2023 to refresh batteries and deploy new SD cards.

Task 4: PLC monitoring on Lookout Mountain

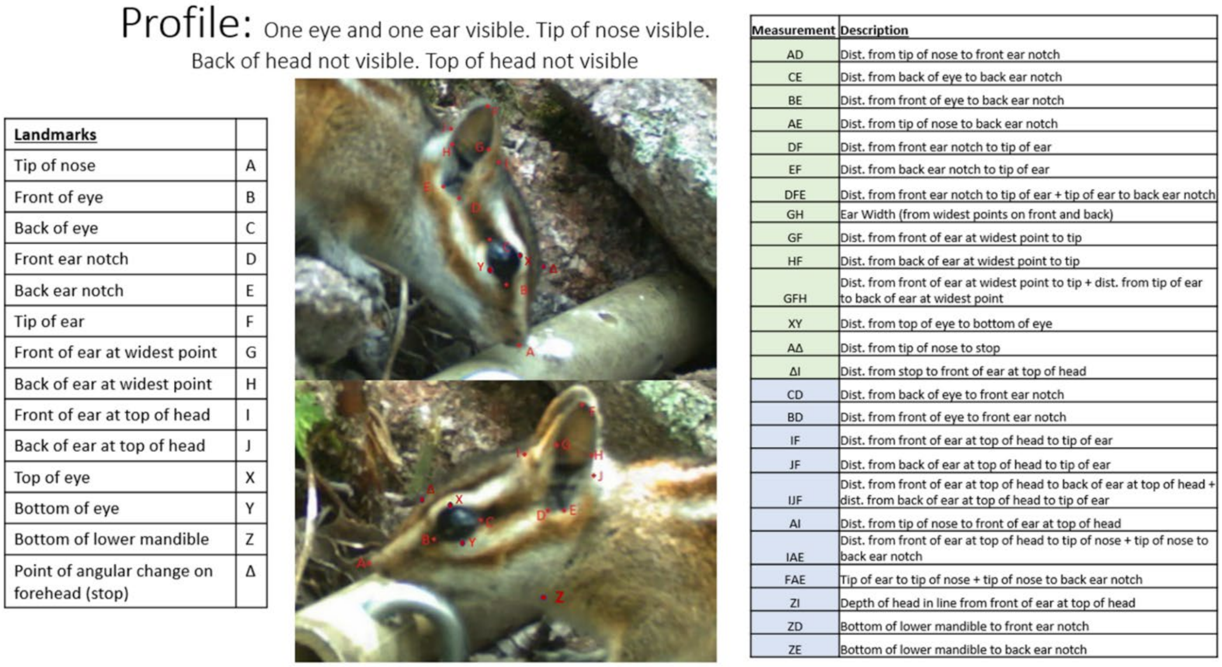
Five sites located in occupied PLC home ranges on Lookout Mountain (Appendix 3) have been continuously monitored since 2019 (McKibben 2022). Remote triggered cameras are deployed at these sites following the methods of McKibben (2022). These sites are in the Lookout Mountain-Ice Springs area of the Sierra Blanca subrange of the Sacramento Mountains. The area is frequently inaccessible due to snow conditions or wildfire closures; however, we attempted to visit the sites for camera maintenance often enough to avoid the batteries from completely discharging or the SD storage capacity from being exceeded between visits.

Task 5: Discrimination of PLC and GFC based on morphology in photographs

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 differentiate photos of GFC and PLC. We used photographs of 39 PLC and 39 GFC taken during a recent field study (McKibben and Frey 2021). 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 the measurements: SmallMeasure and imageJ. 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.

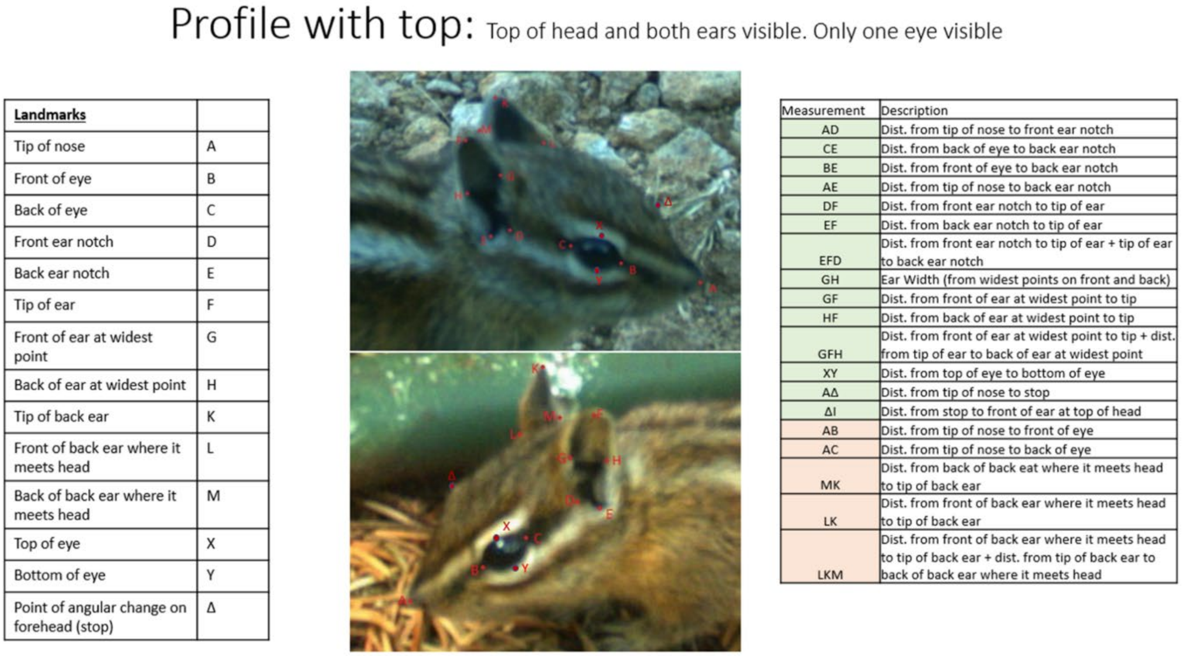


Profile: One eye and one ear visible. Tip of nose visible. Back of head not visible. Top of head not visible

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.

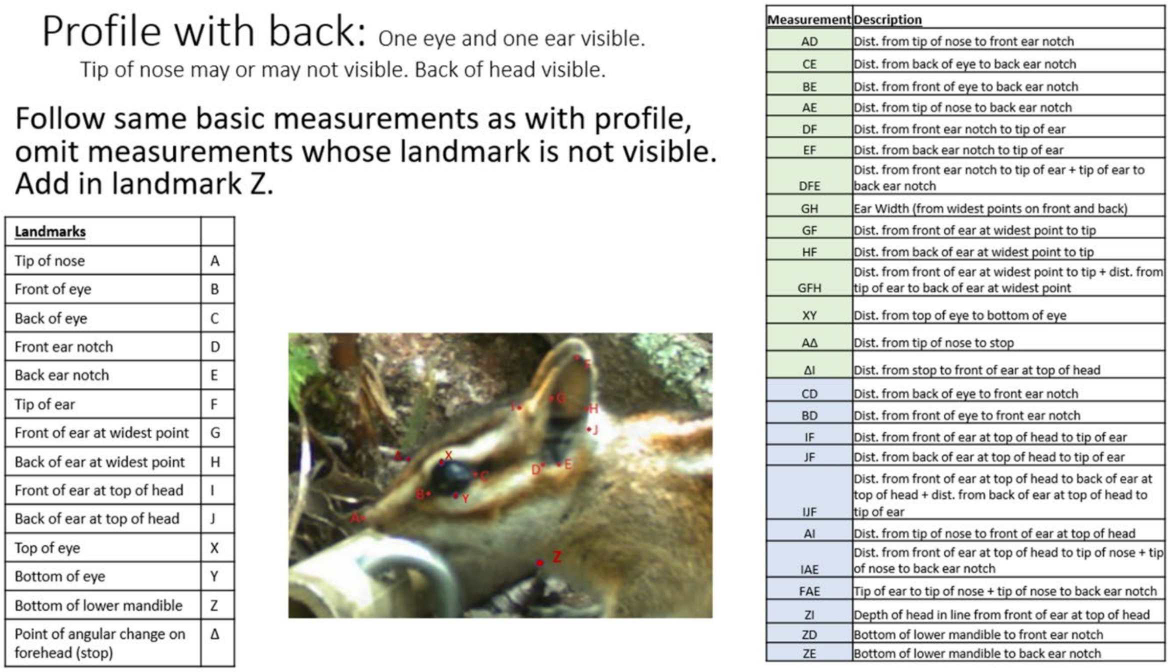


Profile with top: Top of head and both ears visible. Only one eye visible

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.

PRELIMINARY RESULTS

Task 1: Distribution and microhabitat selection of PLC at Nogal Peak

We surveyed 172 sites on Nogal Peak (Figure 4) for a total of 8,491 camera-days (Table 6). Details of survey dates and locations are in Confidential Appendix 1. At least one chipmunk of either species was detected at 129 sites and field habitat data were collected at 96 sites (Table 6). This effort resulted in the collection of > 2.75 million photos (Table 6). Cataloguing and identifying this number of photos posed a logistical challenge and as of the date of this report we have catalogued > 95% of the photos. Of the catalogued photos, 55,015 contained an image of a chipmunk of either species. At the time of this report, photos from five sites have been preliminarily identified as PLC. Efforts to complete the task of cataloguing and accurately identifying the chipmunk photos are ongoing. Upon completion of cataloguing and identifying the photos, we will commence the used-versus-available analysis to evaluate PLC and GFC microhabitat selection on Nogal Peak.

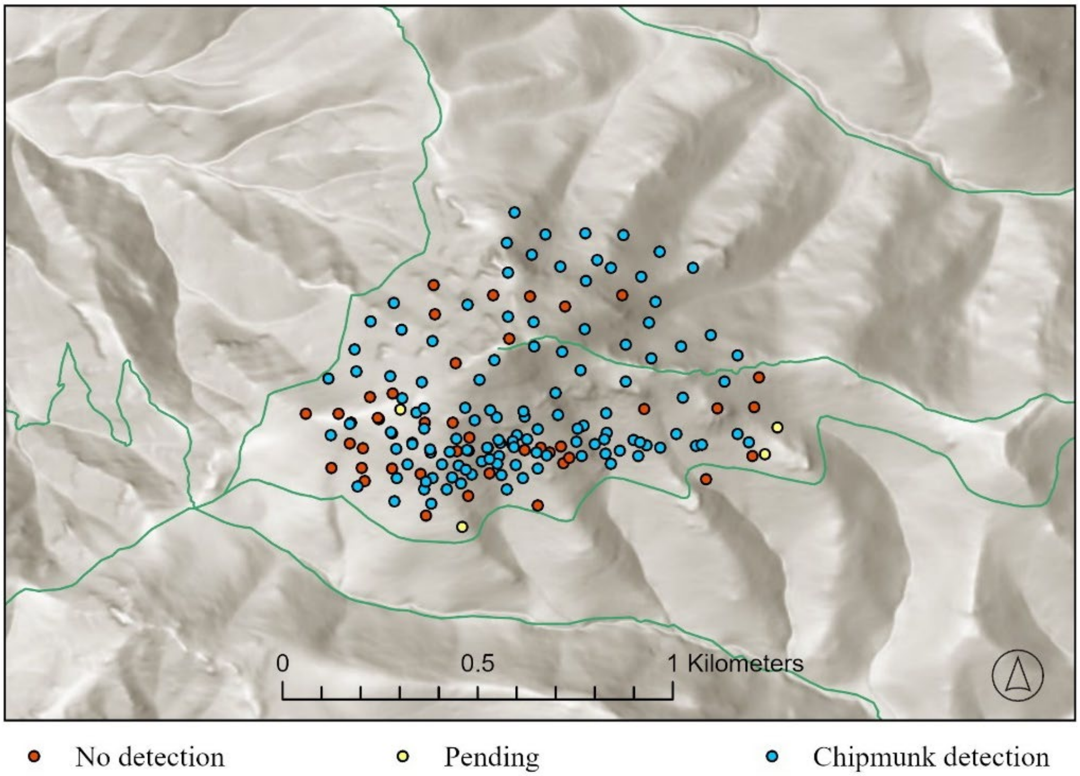


Figure 4. Sites surveyed for PLC and GFC during 2022 – 2023 on Nogal Peak, White Mountain Wilderness Area of the Lincoln National Forest, NM, USA. Sites are categorized as chipmunk of either species detected (blue dot), no chipmunks of either species detected (red dot) or pending (yellow dot).

Table 6. Summary of sites surveyed, camera days, chipmunk detections, vegetation surveys and photos collected during the 2022 (17 June – 20 December 2022) and 2023 (07 April – 30 December 2023) field seasons to date. “Camera days” indicates the number of 24-hour periods the camera was deployed, including time when the camera was out of service due to factors that might include battery failure, SD card capacity exceeded, disturbance by other wildlife, etc. The total number of photos includes photos of chipmunks. “Sites with chipmunk detections” and “Chipmunk photos” include detections of either species of chipmunk. Results indicated by * are as of 13 June 2024.

	Camera sites	**Camera days**	**Sites w/ chipmunk detection**	**Vegetation surveys**	**Total photos collected**	**Chipmunk photos**
2022 field season	69	3,236	54	47	876,067	3,546
2023 field season	103	5,255	75*	49	1,881,839	51,469*
Total	172	8,491	129*	96	2,757,906	55,015*

Task 2: Landscape-scale habitat selection of GFC

GFC detection model. We obtained five competitive GFC detection models (Table 7), four of which contained uninformative parameters based on their 85% confidence intervals and were eliminated, leaving only one competitive model (Model #12). This model included temperature, rock cover, and canopy cover. GFC detection probability decreased with increased maximum daily temperature and percent of canopy cover and increased with increased percent of rock cover (Table 7).

Table 7. Standardized parameter estimates with 85% confidence intervals, degrees of freedom, log likelihood, Δ AICc, and AIC weight for competitive (≤ Δ2 AICc) detection models for *Neotamias canipes* in the Sierra Blanca subrange, Lincoln National Forest, NM, USA. Uninformative parameters are indicated by * (Leroux 2019).

Model	**Int**	**Max Temp**	**Precipitation**	**Scent lure age**	**Survey period**	**Rock cover**	**Canopy cover**	**df**	**logLik**	**Δ AICc**	**weight**
12	-1.433	-0.574				0.307	-0.689	5	-234.817	0.00	0.18
		(-0.886, -0.263)				(0.085, 0.530)	(-0.967, -0.411)				
16	-1.349	-0.624	+			0.328	-0.710	6	-234.068	0.50	0.14
		(-0.941, -0.308)	(-0.846, 0.072)*			(0.104, 0.551)	(-0.987,-0.433)				
44	-1.299	-0.569			+	0.283	-0.679	6	-234.376	1.12	0.10
		(-0.883, -0.255)			(-0.823, 0.175)*	(0.058, 0.507)	(-0.957, -0.401)				
28	-1.505	-0.547		-0.167		0.306	-0.684	6	-234.704	1.77	0.07
		(-0.868, -0.226)		(-0.674, 0.340)*		(0.083, 0.529)	(-0.963, -0.406)				
48	-1.255	-0.612	+		+	0.306	-0.699	7	-233.807	1.98	0.07
		(-0.931, -0.293)	(-0.810, 0.123)*		(-0.758, 0.253)*	(0.080, 0.533)	(-0.976, -0.422)				

Test of three PLC occupancy variables on GFC occupancy. The GFC occupancy model containing the three variables that predict PLC occupancy (elevation, visual obstruction and small-scale edge) was competitive with ≤ Δ2 AICc but failed to perform better than the null model (Table 8). GFC did not have a strong preference for any of the top PLC habitat variables (Table 9). The probability of GFC occupancy in the contemporary PLC range increased with increasing elevation, but the PLC shows a much stronger preference for higher elevations than does the GFC. The probability of GFC occupancy increased slightly with visual obstruction and small-scale edge, however the 85% confidence intervals for both parameter estimates contain 0 so the effects of visual obstruction and small-scale edge on GFC occupancy probability are not significant. These results suggest that the PLC might be exploiting a specific niche at higher elevations and in areas with high visual obstruction provided by shrubs and herbaceous cover along the edges of habitat with trees and thus avoiding competition with the GFC.

Table 8. Standardized parameter estimates, degrees of freedom, Δ AICc and AIC weight for the null GFC occupancy model and GFC occupancy modeled with the three variables in the top occupancy model for PLC in the Sierra Blanca subrange, Lincoln National Forest, NM, USA.

Model	Intercept	Elevation	Visual obstruction	Tree * herb	Tree total	Herb mean	df	Δ AICc	weight
null	-0.902						5	0.00	0.59
1	-0.968	0.457	0.222	0.119	0.004	-0.604	10	0.73	0.41

Table 9. Standardized parameter estimates and 85% confidence intervals for the top occupancy models describing the occupancy of PLC (McKibben 2022) and GFC in the Sierra Blanca subrange, Lincoln National Forest, NM, USA.

Species	Elevation	Visual obstruction	Tree * herb	Tree total	Herb mean
PLC	3.620	1.050	1.170	-0.760	0.850
	(2.45, 4.80)	(0.37, 1.73)	(0.27, 2.07)	(-2.55, 1.03)	(0.20, 1.50)
GFC	0.460	0.220	0.120	0.004	-0.600
	(0.06, 0.85)	(-0.11, 0.54)	(-0.26, 0.50)	(-0.55, 0.56)	(-0.97, -0.24)

Test of 14 PLC occupancy variables on GFC occupancy. There were ten competitive models with ≤ Δ 2 AICc (Table 10). We considered the average of these models as the top model. The top model contained the variables for presence in Engelmann spruce dominated forest, visual obstruction, herbaceous cover, shrub cover, mixed understory cover, elevation and dead tree count (Table 11). The probability of GFC occupancy within the contemporary PLC range increased in areas with Engelmann spruce forests and at sites with increasing visual obstruction and elevation. GFC occupancy decreased with increasing herbaceous and shrub cover. Mixed understory cover and dead tree count were uninformative. Upon preliminary interpretation, these results are consistent with literature that establishes the GFC as primarily forest dwelling, arboreal chipmunk (Best 1992). The GFC is selecting areas within Engelmann spruce forests and avoiding areas with shrubs or herbaceous understory.

Table 10. Standardized parameter estimates, degrees of freedom, log likelihood, Δ AICc, and AIC weight for competitive (≤ Δ2 AICc) occupancy models for GFC in the Sierra Blanca subrange, Lincoln National Forest, NM, USA. The variables for small-scale edge, community, Corkbark fir dominant, open, montane, ecotone, and subalpine edge did not appear in the competitive models.

Model	Int	Shrub cover	Visual obstruction	Herb cover	Mixed understory	Dead Tree count	Engelmann Spruce	Elev	df	logLik	Δ AICc	weight
28	-1.457	-0.835	0.541	-0.845	-0.267		+		10	-226.906	0.000	0.087
32	-1.496			-0.490			+		7	-230.483	0.673	0.062
40	-1.437			-0.556				0.401	7	-230.558	0.821	0.058
2	-1.405	-0.838	0.482	-0.833	-0.243				9	-228.481	0.970	0.054
37	-1.394	-0.737	0.536	-0.863	-0.243			0.361	10	-227.487	1.162	0.049
20	-1.369	-0.787	0.487	-0.892	-0.239	-0.328			10	-227.682	1.552	0.040
25	-1.388			-0.583		-0.363			7	-231.031	1.768	0.036
5	-1.425			-0.495					6	-232.095	1.774	0.036
31	-1.481	-0.514		-0.656	-0.265		+		9	-228.883	1.774	0.036
73	-1.459			-0.555		-0.261	+		8	-229.972	1.791	0.035

Table 11. Standardized parameter estimates and 85% confidence intervals for occupancy variables in the top GFC occupancy model in the Sierra Blanca subrange, Lincoln National Forest, NM, USA. An asterisk indicates an uninformative parameter.

Variable name	Est.	85% CI
Engelmann spruce	0.449	(0.085, 1.921)
Visual obstruction	0.241	(0.112, 1.921)
Herbaceous cover	-0.692	(-1.137, -0.246)
Shrub cover	-0.413	(-1.291, -0.243)
Mixed understory cover	-0.136	(-0.655, 0.150)*
Elevation	0.083	(0.026, 0.739)
Dead tree total	-0.072	(-0.708, 0.073)*

Next steps. We will use the GFC occupancy model with the 14 variables hypothesized to influence PLC occupancy probability (including the three already tested) and compare the chipmunks' responses to each variable. We will also model the probability of GFC occupancy by using the spatial variables used to model PLC occupancy in the PLC spatial model and creating a GFC habitat suitability map that can be directly compared with the PLC habitat suitability map (McKibben 2022). The degree of overlap between the two suitability maps where both species have a high likelihood of occupancy identifies the areas where interactions between the species can be predicted to occur most frequently. Finally, we will use all relevant variables to create a final GFC occupancy model that will evaluate GFC habitat selection in the contemporary PLC range.

Task 3: PLC hibernation

As of the date of this report, we have not been able to retrieve the cameras due to wildfire closures and mandatory evacuation orders for the Blue 2, South Fork, and Salt fires. Eight cameras remain deployed at PLC detection sites (Appendix 2.1). When the restrictions are lifted, we will retrieve the cameras and complete the process of cataloguing and identifying chipmunks in photos from the eight cameras. At that time, we will evaluate the sample size to determine if any valid statistical inferences can be drawn from the recorded data.

Task 4: PLC monitoring on Lookout Mountain

The long-term monitoring cameras were maintained six times (Table 12). Cataloguing and identifying the photos collected at Lookout Mountain is ongoing but presents a major logistical challenge. We are exploring options to utilize automated photo identification software to conduct preliminary sorting and remove non-target photographs.

Table 12. Dates when long-term monitoring cameras were visited for maintenance on Lookout Mountain in the Sierra Blanca subrange, Lincoln National Forest, NM, USA.

Date of Maintenance
28 August 2022
10 November 2022
22 May 2023
22 June 2023
20 July 2023
17 November 2023

Task 5: Discrimination of PLC and GFC based on morphology in photographs

Based on the preliminary analysis of the perfect profile photographs, we found low intra-observer variation (Table 13) and non-significant differences between the results of analyses performed using SmallMeasure vs. analyses using imageJ (Table 14). We found several ratios that suggest there are significant morphological differences between the two species of chipmunks. 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). 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 chipmunks.

Table 13. Comparison of means, sample size, standard deviation, and 95% confidence intervals for selected rations of measurements on two species of chipmunks 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 14. 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

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