2018 YEAR END REPORT

Distribution, abundance, and habitat selection by the Peñasco least chipmunk (*Neotamias minimus atristriatus*) 2018

An adult female Peñasco least chipmunk (*Neotamias minimus atristriatus)* captured 23 August 2018 at Lookout Peak and fitted with a blue ear tag allowing individual identification via photography. Specimen photograph courtesy of Jim Stewart.

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EXECUTIVE SUMMARY

The Peñasco least chipmunk (*Neotamias minimus atristriatus*) has been listed as endangered by the state of New Mexico since 1983, but there are few rigorous data on its distribution or habitat selection. In this pilot study, we evaluated survey methods for implementation in a large-scale occupancy study. We also collected preliminary data on habitat selection and on factors that influence detection rates to inform the design of the occupancy study. Because *N. m. atristriatus* co-occurs with the gray-footed chipmunk (*Neotamias canipes*), a morphologically similar species, we implemented a rigorous experiment to test the reliability of identifications of these species based on photographs taken in a lab setting. We developed and tested a diagnostic key for differentiating between the species using camera trap photographs, and we correctly identified 98.14% of photographs when we reported high confidence in identifications. We compared detection probability for *N. m. atristriatus* between camera traps and live trapping arrays at 20 sites in the Lookout Mountain area, 10 sites on Buck Mountain, and 10 sites on White Horse Hill. We found that detection probabilities were high using both methods, such that 98% detection probability could be attained during 3 days using Sherman trap arrays or 5 days using a camera trap. Because detection probabilities are high using both methods, and because Sherman live trapping is logistically challenging at the high elevation sites where *N. m. atristriatus* persists, we conclude that camera traps are the best method for implementing an occupancy study in the White Mountains. We conducted incidental trapping surveys at Lookout Mountain, Buck Mountain, and Nogal Peak to expand our understanding of the distribution and habitat of *N. m. atristriatus*. Importantly, *N. m. atristriatus* was captured at Nogal Peak, which is an isolated peak in the northern part of the White Mountains and at a lower elevation and vegetation zone as compared with prior known locations. Habitat occupied at Nogal Peak was dominated by deciduous shrubs. Preliminary results suggest that occurrence of *N. m. atristriatus* is limited by habitat specificity and that its distribution in the White Mountains is limited to patches of suitable habitat. Future work will include designing and implementing an occupancy analysis study across the species range in the White Mountains (Lincoln National Forest), and, pending funding, implementing a radio telemetry study at the Nogal Peak and Lookout Mountain study areas.

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I. INTRODUCTION

The Peñasco least chipmunk (*Neotamias minimus atristriatus*) is a candidate for federal listing under the Endangered Species Act (ESA) and has been listed as endangered in the state of New Mexico since 1983 (USFWS 2014; NMDGF 2016). The New Mexico Department of Game and Fish (NMDGF) considers it threatened by habitat alteration, drought, wildfire, and potential competition (NMDGF 2016). In 2011, the US Fish and Wildlife Service (USFWS) was petitioned to list this chipmunk under the Endangered Species Act and in 2012 the USFWS determined that listing of the species was warranted but precluded and designated it a Candidate with high magnitude threats (USFWS 2014).

The subspecies was historically found in two disconnected populations in the Sacramento and White mountains subranges of the Sacramento Mountains. The Sacramento Mountains population has not been verified since 1966, despite intensive sampling (Hope and Frey 2000; Frey and Boykin 2007; Wampler et al. 2008; Frey and Hays 2017). The White Mountains population was verified in 1998, 2000, and 2016 (Ortiz 1999; Hope and Frey 2000; Frey and Hays 2017). However, there is evidence of recent population losses in the White Mountains (Frey and Boykin 2007).

The overall goal of the current study is to critically evaluate the distribution, habitat selection, and ecological interactions of this state endangered species. Our first goal during 2018 was to compare detection rates and efficacy between live trapping and camera trapping survey methods for use in an occupancy model study design. Because *N. m. atristriatus* co-occurs with the gray-footed chipmunk (*Neotamias canipes*), a morphologically similar species, it was first necessary to develop and test a diagnostic key for differentiating between the two species using camera trap photographs. We then conducted paired field surveys using Sherman live trapping and camera trapping methods to compare detection rates. Our second goal during 2018 was to survey historical and new sites for presence of *N. m. atristriatus* in the White Mountains and to collect preliminary data on habitat associations and on factors that may influence detection rates to inform the occupancy model study design, which will be implemented in 2019.

II. EXPERIMENT TO IDENTIFY SYMPATRIC CHIPMUNKS BASED ON PHOTOGRAPHS

Two species of chipmunks are sympatric in the Sacramento-White Mountains, the Peñasco least chipmunk (*Neotamias minimus atristriatus*) and the gray-footed chipmunk (*Neotamias canipes*). We implemented a rigorous experiment to test the reliability of identifications of these species based on photographs taken in a lab setting. Our goal was to answer the following questions:

- What percent of specimens are correctly identified from a single photograph?
- What is the identification rate when observers report high confidence?
- What is the identification rate for *N. m. atristriatus* and for *N. canipes*?
- Which view has the highest identification rate? Which has the lowest?
- Which pelage trait has the highest identification rate? Which has the lowest?
- Which pelage traits perform poorly?

Methods

We used museum specimens with verified identifications as subjects for the photographs taken for this experiment. These included 28 specimens of *N. m. atristriatus* from the Academy of Natural Sciences of Philadelphia and the Museum of Comparative Zoology at Harvard, and 28 specimens of *N. canipes* from the New Mexico State University Wildlife Museum. A laboratory assistant (Kevin Stewart) photographed the specimens using the same high-quality camera (Reconyx PC800 HyperFire) that will be used in the field. All photographs were taken in natural outdoor lighting with the camera set vertically on a surface and the specimen positioned 0.5 m away. Each specimen was photographed from three angles (dorsal, lateral and ventral). The laboratory assistant then curated the photographs into a PowerPoint presentation. For each photograph, the laboratory assistant created three slides that each blocked out parts of the specimen, such that each slide showed only the anterior, middle, or posterior section of the specimen. Thus, there were a total of nine photos per specimen (each showing an isolated nonant of the body; Figure 1). The final PowerPoint presentation consisted of 504 slides (each containing one photograph) that were then randomized. Importantly, the preparation of the PowerPoint presentation was done without direct involvement by the photo identifiers (Frey and McKibben) to prevent any bias.

Independent of the photography and preparation of the PowerPoint presentation, the photo identifiers (Frey and McKibben) developed an initial suite of 17 qualitative pelage traits that we considered potentially useful for distinguishing between the two species (Table 1). These traits were based on quantitative results of prior statistical studies (Frey 2010) and qualitative comparisons of series of specimens observed by us. We created a reference sheet that detailed the traits and provided instructions for coding each photograph in the PowerPoint presentation. We then used this information to code each photograph for each of the 17 pelage traits (1: best represents trait for *N. m. atristriatus*, 2: best represents trait for *N. canipes*, 0: unknown/can't see feature) and also assigned a species to each photo based on the observer's overall impression. In addition, we reported a numeric confidence rank from 1 to 4 for each photograph, based on how confident we were in assigning the species identification, from very confident (4), somewhat confident (3), not very confident (2), to no confidence (1).

Each photograph was coded by both of us, resulting in a total of 1,008 photographs coded for 19 characters (17 pelage trait, 1 overall species identification, 1 reliability of overall species identification), for a grand total of 19,152 data cells coded and analyzed. Because our photographs were of museum specimens with verified identifications, data analysis involved descriptive statistics, such as means, and determination of correct identification rates.

Preliminary Results and Implications:

- *What percent of specimens are correctly identified from a single photograph?* Out of 1,008 photographs coded, we correctly identified 90.67% of the specimens.
    - **Implications** – identification rates are high enough to warrant using camera traps to survey for *N. m. atristriatus*.

- *What is the identification rate when observers report high confidence?* When confidence was 4 (very confident) we correctly identified 100% of the specimens (n=293). When confidence was 3 or 4 (somewhat confident to very confident; n = 634) we correctly identified 98.14% of the specimens.
    - **Implications** – if we identify photos with high confidence, our identifications are more reliable.

- *What is the identification rate for N. m. atristriatus and for N. canipes?* We correctly identified the species for 97.22% of *N. m. atristriatus* photographs (n=504) and 84.13% of *N. canipes* photographs (n=504). Among the misidentifications, 92.86% (13 out of 14) of those for *N. m. atristriatus* had lower confidence (numeric confidence rank of 1 or 2), and 86.25% (69 out of 80) of those for *N. canipes* had lower confidence. The other 11 (13.87%) misidentified *N. canipes* photographs were coded as somewhat confident (numeric confidence rank 3); however, these 11 photographs mostly contained pelage traits that did not perform well discriminating between the species, such as ventral tail color pattern.
    - **Implications** – we can be confident in our ability to identify *N. m. atristriatus*, but should be wary of potential for false positives. Some of the characters commonly contributing to false positives included posterior belly and ventral tail.

- *Which view has the highest identification rate? Which has the lowest?* Overall, anterior views had the highest correct identification rates (mean=94.35%) and the anterior ventral view had the highest correct identification rate (96.43%; Figure 2). Across the three middle views, all had high (> 90%) correct identification rates. The posterior views had the overall worst performance (only 1 of 3 having >90% correct identification rate), and included the lowest correct identification rate (77.68%) for the posterior ventral view. However, the posterior lateral view had a relatively high correct identification rate (92.86%). Among dorsal, lateral, and ventral views, there was no overall difference, except for the notably lower correct identification rate for the posterior ventral view. Confidence of identification varied by view and did not appear to be directly related to correct identification rate. For instance, we reported relatively low confidence when coding middle ventral view photos, and yet we correctly identified 91.07% of these photos (Figure 2).

  - **Implications** – the posterior ventral view provides relatively inconclusive pelage traits. We should design our camera trap mounts to capture dorsal and lateral views. The anterior, middle and posterior angles all have views that can support confident identifications and we anticipate that a living animal will provide multiple of these angles.

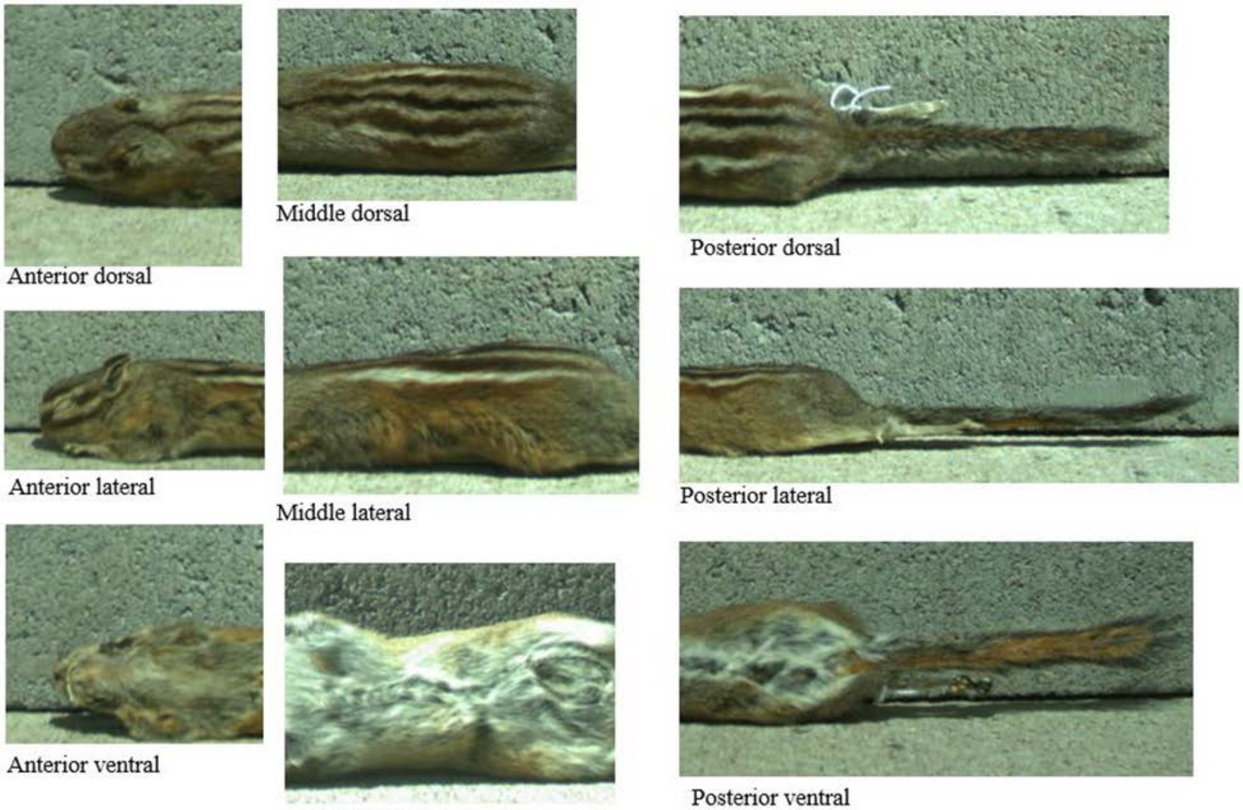
- *Which pelage trait has the highest identification rate? Which has the lowest?* Correct identification of traits varied from 96.24% for underside of front leg to 78.51% for ventral tail. However, we both reported difficulty coding individual characters independently from our impression of the suite of traits observable on a photograph. For example, we both felt that crown color was a poor diagnostic character, but it was often coded correctly. We think this was because we were unable to view specific traits in isolation, and hence were influenced by more obvious traits such as post-auricular patch or upper light face stripe. We will eliminate crown from the diagnostic character key.
  - **Implications** – to determine the value of individual traits for identification, we would need to isolate traits alone and code them independently of the rest of the animal.

- *Which pelage traits perform poorly?* To estimate which traits contributed to incorrect identifications, we summarized pelage traits that were linked to a misidentification in the overall evaluation and were also coded with the incorrect species for that particular trait. Traits were counted as being “linked to misidentifications" if they were both coded with the wrong species for the overall identification and had the matching wrong species coded for the particular trait. Nine of the pelage traits were linked to misidentifications on less than 5% of the instances when they were coded and an additional six were linked to misidentifications on less than 10% of instances when they were coded. Ventral tail was linked to misidentifications 21.49% of the time when it was used and so we will eliminate this trait from the diagnostic character key. Although belly and underside of back leg both performed poorly (linked to misidentification 9.52% and 12.96% of the time respectively), the difference in coding between the two observers implies that the traits themselves may still be useful. McKibben linked belly to misidentifications 5.36% of the time, while Frey linked belly to misidentifications 13.69%. McKibben linked underside of back leg to misidentifications 6.06% of the time, while Frey linked the trait to misidentifications 17.71% of the time. Frey reported feeling that these characters were described incorrectly in the initial description of qualitative character traits (Table 1), which strongly influenced her coding, while McKibben reported adjusting her coding slightly as she gained a clearer standard image for the color difference. We will not eliminate these traits, but will adjust the definitions.
  - **Implications** – in line with our previous conclusion, the traits visible from a posterior ventral view proved relatively inconclusive. However, adjusting our definitions may lead to more correct identifications. Furthermore, although individual traits may be performing poorly, we are gleaning something else from the photos and making correct identifications more than 77.68% of the

time (posterior ventral view correct identification rate), even when only poorly performing traits are visible.

Conclusions

Results indicate that the two species can be reliably identified based on photographs by people with appropriate experience and training. In reviewing these results, it should be kept in mind that the identifications were based solely on observations of small sections of the body in isolation (i.e., the body nonants), and yet correct identification rates were almost always very high. We have revised the definitions for belly and underside of back leg in the character key, and crown and ventral tail have been removed from the key (Table 2). In the future, we will repeat the coding and analyses, but this time based on the refined key and using larger views of the body. Further, the results for reliability coding demonstrated that the observers were aware when photographs could not be conclusively identified. We conclude that the two species can be reliably identified based on photographs.



Middle dorsal

Posterior dorsal

Anterior dorsal

Anterior lateral

Middle lateral

Posterior lateral

Anterior ventral

Posterior ventral

Middle ventral

Figure 1. Specimen photos of *Neotamias minimus atristriatus* and *N. canipes* taken with Reconyx PC800 HyperFire cameras from a distance of 0.5 m, with examples of all nine views.

Table 1. Preliminary suite of 17 pelage traits tested to identify *Neotamias minimus atristriatus* and *N. canipes* from photographs

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

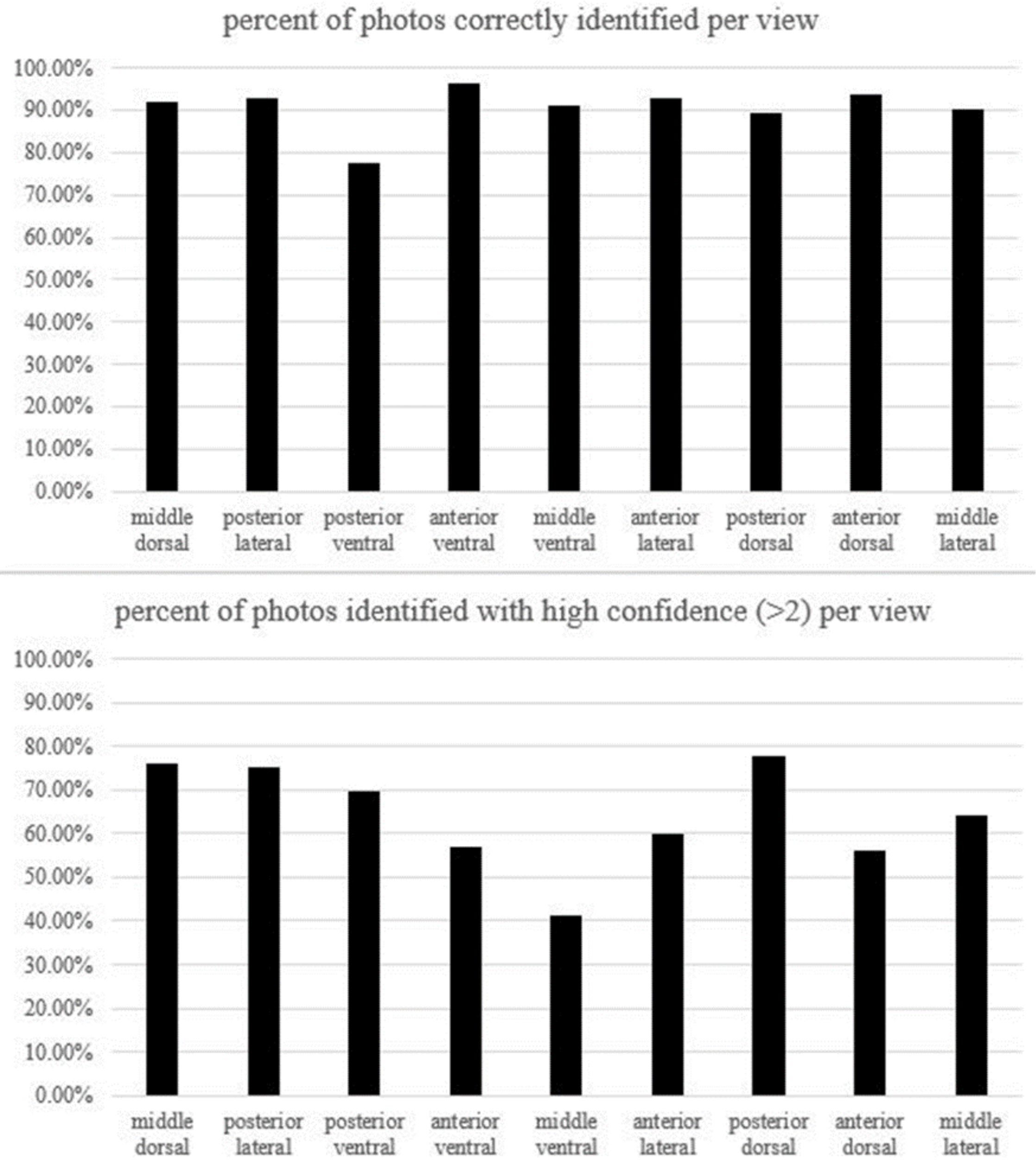


Figure 2. Comparison of percent of photos correctly identified by view and percent of photos identified with high confidence by view.

Table 2. Revised diagnostic key for differentiating *Neotamias minimus atristriatus* and *N. canipes* from photographs

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

*Note: this key should only be used to identify chipmunks by people with appropriate experience and training
**Revisions to belly and underside of back leg are underlined and bold, and crown and ventral tail have been removed from this key.

III. Comparing Detection Rates between Live Trapping and Camera Trapping

Study Area

Surveys occurred during late June to mid-September because *N. m. atristriatus* goes into a seasonal torpor during the winter months. We surveyed sites in the White Mountains, Lincoln National Forest, beginning at sites near historic capture locations on Lookout Mountain and Buck Mountain, and moving to adjacent areas. The survey areas are shown in Figure 3 and were named: 1) Buck Mountain; 2) Lookout Mountain, which includes 4 subareas: Lookout Peak, Ice Springs, Prospect Ridge (meadow approximately 1 km west of Ice Springs), and Crest Trail (T-25 located on a west-facing meadow approximately 1.6 km north of the summit of Lookout Mountain); 3) White Horse Hill; and 4) Nogal Peak. All sites except Buck Mountain and Lookout Peak were entirely or partially within the White Mountains Wilderness Area.

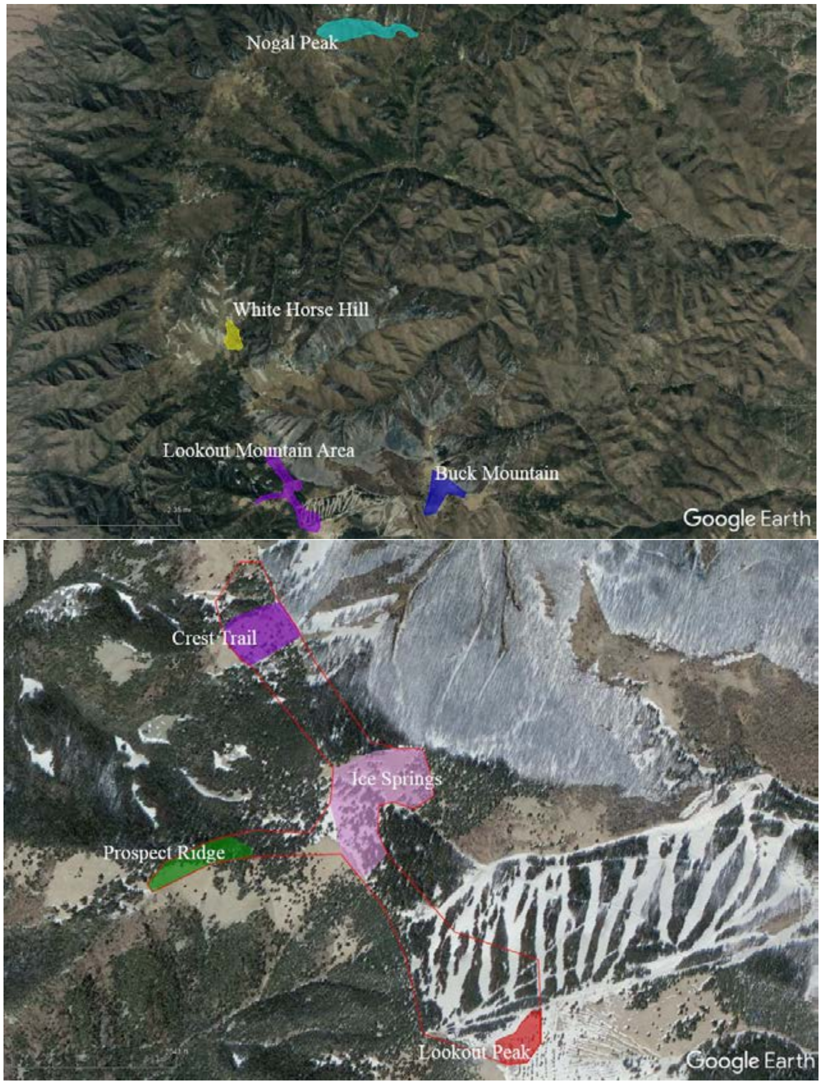


Figure 3. Map of study areas (polygons) surveyed for *Neotamias minimus atristriatus* in the White Mountains, Lincoln National Forest, New Mexico. Top image shows entire study area. Bottom image shows subareas within the Lookout Mountain study area.

Field Methods

The fieldwork occurred 21 June to 14 August and included 40 locations at 6 of 7 study sites (location, dates, and survey efforts are in Table 3; no paired surveys conducted at Nogal Peak). At each location a remote camera (Reconyx PC800 HyperFire) was mounted vertically approximately 45 cm above the ground using a PVC frame, which was moored to the ground with a tent stake (Figure 4). The camera trap was baited with peanut butter placed inside a PVC tube with holes to allow scent to escape. The bait tube was positioned roughly 1 m from the camera and was secured to the ground with a tent stake. The number of camera survey days at a site were varied depending on logistics and to test changes in detection depending on length of time cameras were deployed. All cameras were deployed in habitats with a combination of bunch grass, currant and/or gooseberry, and rock cover. Lab assistants (James Mackenzie, Danica Cooke, and Sabrina Lucero) coded camera trap photos using the Colorado Parks Warehouse (CPW) database, tagging each photo with species or genus. Photographs of either species of chipmunk were tagged as "chipmunk" and were pulled out of the database for further identification. Photographs taken within a three-minute period were placed together in a folder, because a three-minute period generally reflected the maximum time a single chipmunk spent at a bait tube. A lab assistant (James Mackenzie) randomized the folders, so that we were blind to the camera trap location associated with the photographs when we coded species. We used the reference sheet of qualitative pelage traits (Table 1) to code each chipmunk, following the protocol used for photo-based identifications. If a set of photographs appeared to contain multiple individual chipmunks, we coded pelage traits of each chipmunk separately. When determining detections, we only used occasions where the chipmunk was identified to species with higher confidence (reported confidence rank of 3 or 4).

For a subset of the camera trapping period, we trapped concurrently using Sherman live traps at the camera locations. Sherman trap arrays consisted of 17 traps spaced 5 m apart on perpendicular transects radiating from the camera trap location, with one trap at the center and four traps along each spoke. Traps were baited with oats and peanut butter. Trap arrays were closed for the rest of the day after a chipmunk capture, to avoid stressing individuals. We used the reference sheet of qualitative pelage traits (Table 1) to code each chipmunk caught in a live trap for every trait, following the protocol used for photo-based identifications. Identifications of live-captured individuals were based on pelage characters and external morphological features. For each live-captured *N. m. atristriatus*, we collected data on tail length, hindfoot length, ear length, mass, sex, and reproductive status, as well as collecting ear clippings and marking individuals with broad permanent Sharpie markers to identify recaptures. We collected fecal samples opportunistically.

Figure 4. Camera mounting stand and bait tube. The stand and bait tube are anchored to the ground with tent stakes.

Detection Model Methods

We used the unmarked and MuMin packages in R to compare preliminary detection probabilities between the two survey methods (camera and live trapping). We tested detection using naïve models that held occupancy and detection probabilities constant. A constant model does not account for differences in occupancy or detection between sites or between surveys; it simply provides a rough baseline estimate for occupancy and detection probabilities (i.e., it provides the detection probability per survey [i.e., trap day] given constant detection between sites and surveys). Because Sherman live trapping and camera trapping partially overlapped in time, we tested camera trap detection probabilities both including and not including survey occasions with simultaneous live trapping. We hypothesized that detection probabilities for camera traps would decrease during simultaneous live trapping periods. Chipmunks may be discouraged from visiting sites due to frequent disturbance by researchers while conducting live trapping efforts. Likewise, chipmunks may be caught in peripheral live traps before making it to the center of a trapping array, and so never have a chance to investigate the bait tube and be caught on camera.

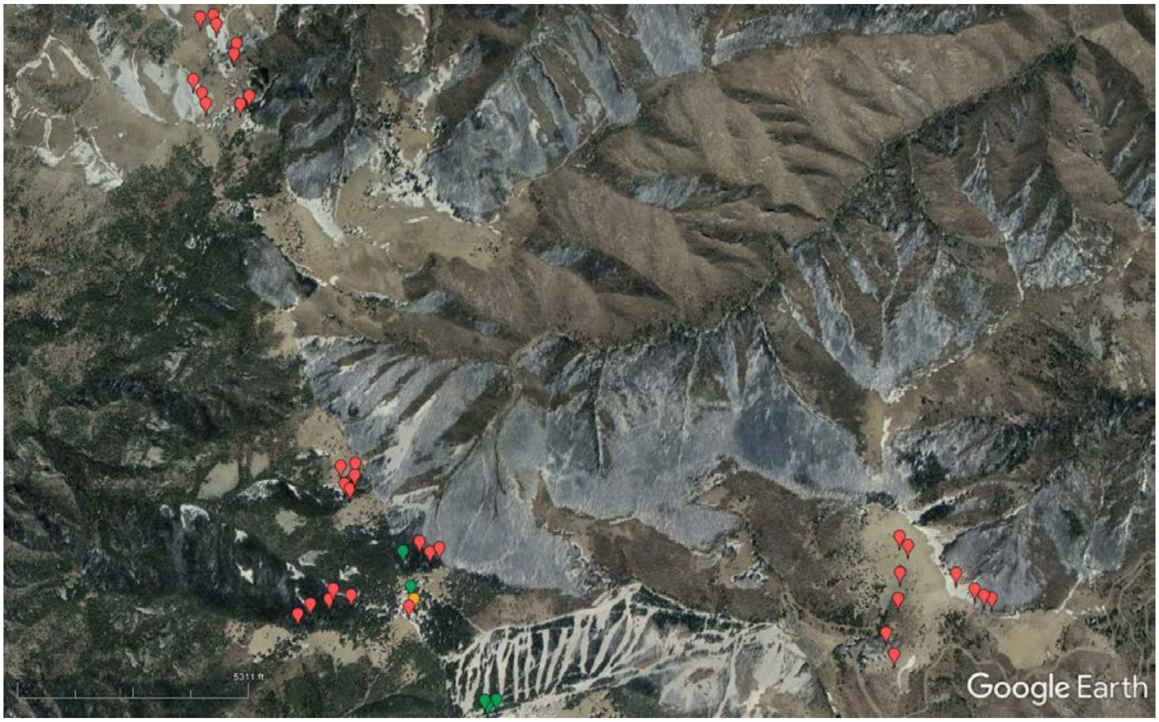


Figure 5. Survey locations during paired camera and Sherman live trapping surveys. Green pins indicate locations where *Neotamias minimus atristriatus* was detected using camera and live traps, yellow pins indicate locations where *N. m. atristriatus* was detected only using camera traps, and red pins indicate no *N. m. atristriatus* captured during paired surveys. Shows Buck Mountain, Lookout Peak, Ice Springs, Crest Trail, Prospect Ridge, and White Horse Hill.

Figure 6. Camera trap photographs from Lookout Peak and Ice Springs. Top photos show *Neotamias minimus atristriatus* and bottom photos show *N. canipes*.

Detection probabilities for *N. minimus atristriatus* using Sherman live trapping and camera trapping were high (Table 5). The daily detection probability using living trapping was 0.781. The daily detection probability using camera traps was 0.452 when calculated based on the full camera dataset. However, detection probability using cameras increased to 0.542 when excluding days that Sherman trapping occurred. This suggests that human activity associated with Sherman trapping significantly decreased camera detection probabilities, probably due to altered behavior (predator avoidance) by the chipmunks. At an occupied site, the probability of detecting *N. m. atristriatus* at least once reaches 98% by day 3 for Sherman trapping and by day 5 for camera trapping (Figure 7). These results indicate that where *N. atristriatus* is present, it is readily detected by either Sherman trapping or camera trapping. This provides high reliability that *N. m. atristriatus* was not present at locations surveyed where it was not detected.

Table 5. Naïve estimates of occupancy and detection during paired surveys for *Neotamias minimus atristriatus* using Sherman live traps and remote camera traps.

Trapping method	Species	Occupancy estimate	SE	P(>|z|)	Occupancy probability	Detection estimate	SE	Detection probability	P(>|z|)
Sherman	*N. m. atristriatus*	-1.94	0.479	0.000	0.126	1.27	0.671	0.781	0.059
Camera-all days	*N. m. atristriatus*	-1.7	0.444	0.000	0.154	-0.193	0.307	0.452	0.530
Camera- excludes Sherman trapping days	*N. m. atristriatus*	-1.65	0.448	0.000	0.161	0.17	0.397	0.542	0.670
Sherman	*N. canipes*	4.98	63.5	0.937	0.993	-4.22	0.837	0.014	0.000
Camera	*N. canipes*	-2.02	0.54	0.000	0.117	-0.614	0.448	0.351	0.171

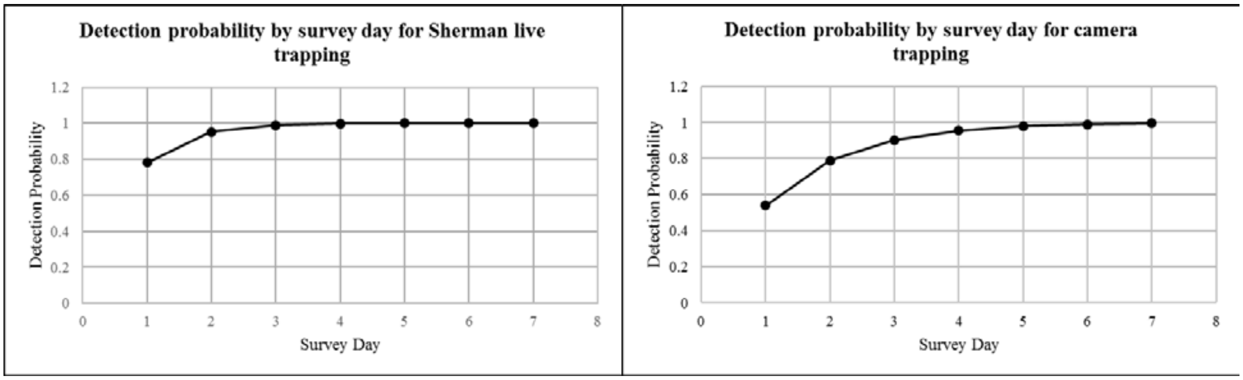


Figure 7. Naïve detection probability by survey day for live traps (left) and camera traps (right). Naïve detection probability reaches 98% by day 3 for Sherman trapping and day 5 for camera trapping.

IV. INCIDENTAL SURVEYS

Methods

We used Sherman live trapping to survey for *N. m. atristriatus* in new habitat types and at new locations (Figure 8). During these incidental surveys, Sherman traps were set in informal lines of roughly 40 traps spaced ca 5 m apart and targeting different types of habitat in an exploratory manner. These surveys included 320 trap days at Lookout Peak and Ice Springs targeting shrubs and sparse trees during 23-25 August, 240 trap days at Buck Mountain during 2-3 September targeting areas with shrubs, and 1,440 trap days at Nogal Peak to test occurrence in a new location with a diverse and abundant shrub matrix (Table 6).

Results

Capture locations in the Lookout Mountain region were in association with gooseberry currant (*R. montigenum*), Thurber's fescue (*Festuca thurberii.*), and sparse conifer trees. During incidental surveys at Lookout Peak, we caught 13 *N. m. atristriatus* and one unidentified *Neotamias* in areas with low-lying thickets of gooseberry currant (*R. montigenum*) and shrub-like Englemann's spruce (*Picea engelmannii*) (Table 6, Figure 9). At Ice Springs, we caught 3 *N. m. atristriatus* associated with thick gooseberry currant (*R. montigenum)* and sparse Englemann's spruce (*P. engelmannii*; Table 6, Figure 9). At Buck Mountain, we did not capture any *N. m. atristriatus* but caught 2 *N. canipes* in burnt forest with downed trees, thick lupine, and a thick and abundant shrub matrix (Table 6).

At Nogal Peak, we caught 3 *N. canipes* and 5 *N. m. atristriatus* (Table 6, Figures 10 and 11). The captures of *N. m. atristriatus* on Nogal Peak represent a significant new locality of record. This site was lower in elevation (~ 9,400 ft) and within the upper montane conifer forest zone (in contrast Lookout Mountain and Sierra Blanca records are from the higher subalpine and alpine zones > 11,000 ft). The *N. m. atristriatus* on Nogal Peak were associated with a thick and diverse shrub community, including Gambel's oak shrub (*Quercus gambelii*), snowberry (*Symphoricarpus oreophilus*), and New Mexico locust (*Robinia neomexicana*) (Figure 11). Thus, the Nogal Peak captures expand our understanding of *N. m. atristriatus* habitat in the White Mountains.

Figure 8. Survey locations for all trapping methods (live trap arrays, camera traps, incidental trap lines). Blue pins indicate *Neotamias canipes*; yellow pins indicate *N. minimus atristriatus*; green pins indicate both species captured; red pins indicate no chipmunks captured. Top shows Buck Mountain, Lookout Peak, Ice Springs, Crest Trail, and Prospect Ridge capture sites; bottom shows close-up of Ice Springs.

Figure 9. *Neotamias minimus atristriatus* capture locations during incidental surveys. Top photo shows Ice Springs location and bottom photo shows Lookout Peak location.

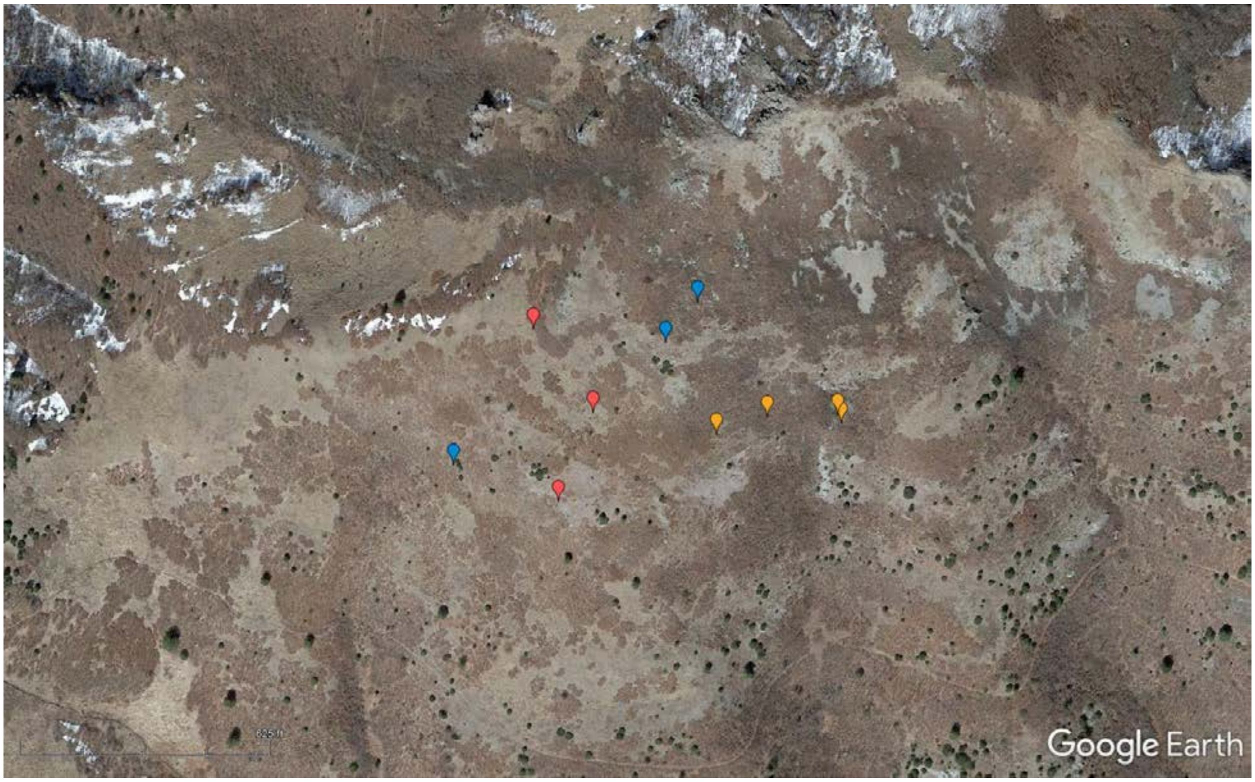


Figure 10. Nogal Peak incidental survey locations. Yellow pins indicate *Neotamias minimus atristriatus* captures, blue pins indicate *N. canipes* captures, and red pins indicate survey locations with no chipmunk captures.

Figure 11. *Neotamias minimus atristriatus* capture locations on Nogal Peak. The person is standing at one capture location and a pink flag in the foreground indicates a second capture location.

V. MICROHABITAT DATA COLLECTION

During 20 July to 3 September we collected microhabitat data at the 40 camera trap locations at Buck Mountain, Lookout Peak, Ice Springs, Prospect Ridge, Crest Trail, and White Horse Hill. During 18 September to 4 October, we collected microhabitat data at Nogal Peak, at 3 locations where *N. m. atristriatus* was captured and at 5 traplines that did not capture *N. m. atristriatus.* On traplines, the location for microhabitat data collection was a trap location near the center of the line with representative habitat.

At each of the 48 habitat plots, we collected ground cover and plant composition data on four equally spaced 40 m transects radiating from the survey site center, which was the camera trap location for the paired camera trap and live trap survey sites. Direction of the first transect was selected at random, and the other three transects radiated at 90° increments. Every tree >10cm diameter at breast height (dbh) within one meter of each transect was counted, identified to species, and assigned to a 10cm dbh size class. Every boulder >0.5m width within 1m of each transect was counted. Every stump, defined as a dead tree still rooted <1m high, within 1m of each transect was counted. Every log >10cm diameter within 1m of each transect was counted. Visual cover was measured using a Robel pole every 2m along the 40m transects (Robel readings were always taken on the right-hand side of transects). The Robel pole was read in inches at 1m eye level from a 4m distance, going perpendicularly away from the transect and towards the transect, resulting in two readings per 2m increment along the transect. Ground cover was recorded every 2m using a 20x50-cm Daubenmire plot and classing categories (0-5%, 5-25%, 25-50%, 50-75%, 75-95%, >95%). Classes included: *Lupinus sp.* (lupin), *Achillea millefolium* (yarrow), *Iris missouriensis* (mountain iris), *Campanula rotundifolia* (bluebell), *Artemisia sp.* (sage), other forb, *Festuca sp.* (fescue), other grass, *R. montigenum, R. pinetorum* (orange gooseberry), *R. wolfii* (Winaha currant), *Q. gambelii, S. oreophilus, R. neomexicana, Fallugia paradoxa* (Apache plume), *Holodiscus dumosus* (mountain spray), other shrub, coniferous tree, deciduous tree, bare ground, acorns and pine cones, log >10cm, rock 10cm-1m, boulder 1m-5m, and unbroken bedrock/large boulder >5m. Canopy cover was measured in four directions from the trap site and every 20m along transects using a convex spherical densitometer. From the survey site center, we recorded distance to nearest boulder >0.5m, distance to nearest stump, distance to nearest log, distance to and species of nearest tree >10cm dbh, and distance to and species of nearest shrub (woody plant with multiple stems). All distances were limited to within 10 m of the survey site center, because Clarke (1993) found that *Neotamias* spp. will flee approximately 10 m (5.4 ± 0.3m when near their burrows, 11.4 ± 0.7m when outside their home range). We deployed DS1923 Hygrochron iButtons (Thermodata, Whitewater, WI, USA) by taping to the camera to record temperature at every camera trap site. These data have not been analyzed.

VI. DISCUSSION

N. minimus atristriatus is only known to persist in the White Mountains, most of which is in a remote, rugged, high elevation Wilderness Area, accessible only via backcountry trails and usually lacking sources of drinking water. At this remote site, traditional live trapping methods are logistically challenging. Weather patterns shift rapidly, often resulting in violent storms that pose risk to both researchers and animals. Live traps must be constantly monitored and closed when storms approach to prevent trap mortalities. Traditional live trapping methods require grids or trap lines of hundreds of traps set and monitored at each survey site. The logistics of transporting hundreds of traps into a wilderness area, and monitoring traps appropriately, would limit the total number of sites that could surveyed and may pose unacceptable risk to researchers and animals. Live trapping in this environment also presents ethical concerns about leaving animals in traps when researchers must vacate a location unexpectedly due to human safety needs in the face of extreme weather. Because of the logistical and ethical concerns of using live trapping methods to survey for least chipmunks in the White Mountains, camera traps would potentially be a good alternative, if it were determined to be possible to reliably identify *N. minimus atristriatus* from photographs.

Our comprehensive test to determine if *N. m. atristriatus* can be distinguished from the co-occurring, congeneric chipmunk species (*N. canipes*) demonstrated that these species can be reliably identified based on photographs and the diagnostic key we developed. The results further indicated that people with appropriate experience and training were aware when photographs could not be conclusively identified. Thus, we conclude that the two species can be identified with high reliability based on photographs. In addition, our field test that directly compared detection probabilities between Sherman live trap arrays and remote camera traps found that both methods resulted in high and comparable detection probabilities. Where the species is present, > 98% detection probability is achieved in 3 days using arrays of 17 Sherman trap arrays and 5 days using a single camera trap. Part of the reason a single camera trap preforms comparably to an array of Sherman traps is that the frequent human presence required by Sherman trapping appears to alter chipmunk behavior and reduce detection. Further, the logistics, labour, human safety, and animal safety are far superior using remote cameras as opposed to Sherman traps. Each location surveyed requires only deployment of a single camera that can be left to collect data noninvasively for numerous days until it is retrieved. This prevents animal mortality, reduces risk to human researchers, and simplifies logistics. In addition, camera traps are ideally suited to occupancy modeling methods.

Camera traps are well-suited to occupancy analysis, which only requires detection/non-detection data. Camera traps have been used successfully for occupancy analysis in studies of large mammals, such as sun bears and brown hyaenas (Linkie et al. 2007; Thorn et al. 2008). De Bondi et al (2010) directly compared live trapping to camera trapping for small mammals and found that camera trap surveys detected similar species and were more efficient and cost effective. Perkins-Taylor and Frey (2018) used camera traps for their occupancy analysis of the Oscura Mountain Colorado chipmunk (*Neotamias quadrivittatus oscuraensis*). Although a single camera may have a lower detection probability than a live trap array, a camera can be left to run for multiple days, efficiently capturing multiple independent surveys without the presence of researchers. Finally, camera traps are non-invasive, with no chance of trap-related mortality, which is ideal when working in a high elevation location with frequent storms and changing weather. Thus, surveys for our occupancy model study will be conducted using cameras.

Our preliminary results also contribute to our understanding of the distribution and habitat associations of *N. m. atristriatus.* Importantly, we discovered a significant new location for the species at Nogal Peak. Nogal Peak is located in the northern portion of the White Mountains, approximately 12 km north of Lookout Mountain. This peak is lower in elevation (9,907 ft) than all other mountains where the species has been recorded in the White Mountains (Sierra Blanca, Lookout Mountain, Buck Mountain). The capture locations were ~9,400 ft on the south-facing aspect of the mountain. The vegetation zone is upper montane coniferous forest, rather than subalpine or alpine as on Lookout Mountain and Sierra Blanca. The vegetation association was composed of diverse shrubs and appeared to be an old post fire seral stage of upper montane coniferous forest, based on presence of occasional ponderosa pine, Douglas fir, pinyon, and juniper. While *N. m. atristriatus* is known to have occurred primarily in the montane coniferous forest zone in the Sacramento Mountains, this is the first record of it in this zone in the White Mountains. Thus, the distribution and habitat associations for the species in the White Mountains are larger than previously known.

Despite the discovery of a new population in a new habitat association, our preliminary results also suggest that the distribution of *N. m. atristriatus* in the White Mountains is patchy and that most habitat types are unoccupied. For instance, no *N. m. atristriatus* were captured at Buck Mountain or White Horse Hill, both of which are prominent peaks situated between Lookout Mountain and Nogal Peak. Further, no *N. m. atristriatus* were detected at the Crest Trail or Prospect Ridge subareas of Lookout Mountain. This suggests that the species' distribution is regulated by specific, as yet undiscovered, factors. We observed no evidence of illness in either species of chipmunk. Our results suggest that *N. m. atristriatus* does not use dense conifer forest or open Thurber fescue meadow lacking deciduous shrubs or scattered trees. Our results also suggest that rocks may not be essential components of habitat. The local occurrence of *N. m. atristriatus* and *N. canipes* were largely non-overlapping. Thus, distribution of *N. canipes* could be influencing habitat selection by *N. m. atristriatus* via competition as is often the case for pairs of larger and smaller sympatric chipmunks. Our preliminary working hypothesis is that *N. m. atristriatus* primarily selects areas supporting deciduous shrubs, which provide both low concealment cover and abundant non-conifer food items. Further information on habitat associations will require analysis of the preliminary habitat dataset and testing using future occupancy models and radio telemetry data.

VII. FUTURE WORK

Future work will include further analysis and testing of the camera trap photograph identification experiment, analyses of habitat data collected in 2018 to inform development of the occupancy study planned for 2019, implementation of a full-scale occupancy study, and implementation of a radio telemetry study in two populations.

Experiment to identify sympatric chipmunks based on photographs – Results from our camera trap photograph identification experiment indicate that photographs of the two sympatric species of chipmunk can be reliably identified. We will revise the diagnostic key trait descriptions for belly and underside of back leg, and crown and ventral tail will be removed from the key. We will repeat the coding and analyses performed in 2018, but this time based on the refined key and using larger views of the body. This will bolster the evidence that our ability to identify camera trap photographs is sufficient to conduct a large scale camera trap survey.

Occupancy study – We will implement a full scale occupancy study across the White Mountains Wilderness Area during the summer of 2019. Before beginning this work, we will use further analysis of current data to inform our study design and site selection. We will analyze the habitat data to discover variables that can be tested as covariates of detection and occupancy. Using the detection and occupancy estimates from the constant model, we will run data simulations to help select a number of survey sites and a number of survey occasions (the number of days cameras are run per site). With data simulations, we can test a range of estimates of probability of detection to determine how many survey occasions are necessary to detect the species at an occupied site and the number of sites that should be surveyed.

Using microhabitat data from the first field season, we will test for covariates that influence detection probability. Understanding these covariates may inform camera trap and bait tube placement at 2019 survey sites. We will also test for covariates that influence probability of occupancy, which may help inform survey site selection. We will survey major habitat types present in the White Mountains that provide potential chipmunk habitat: meadow, talus/rock field, alpine tundra, conifer forest, aspen forest, burnt forest, and disturbed/ski run. We will create a randomly generated set of points with sites in every habitat type, distributed roughly in proportion to the availability of each habitat type across the entire study area.

Radio telemetry study – While an occupancy study through camera trapping will allow us to evaluate habitat selection on the landscape scale, species can select different habitat factors at different spatial scales. Johnson (1980) describes four scales of habitat selection: landscape (physical or geographical range); macro-habitat (home range of a group or individual); micro-habitat (use of habitat within a home range); and selection of food items. Radio telemetry can give fine scale information on macro- and micro-habitat selection, as well as elucidating key natural history characteristics, such as movement patterns, home range size, home range selection, den site selection, and feeding behavior (Wright & Frey 2015). Based on our 2018 surveys, we have identified two populations (Ice Springs and Nogal Peak) with local abundances large enough to support an investigation through radio telemetry. Importantly, the two populations occur in significantly distinct habitat types, potentially allowing us to better extrapolate selection factors across a broader landscape.

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