FINAL REPORT

Surveys for the Peñasco least chipmunk (*Tamias minimus atristriatus*) 2016

Peñasco least chipmunk (*Tamias minimus atristriatus*) captured 29 June 2016,
1 km NW Lookout Mountain, Trail T78 SW Ice Spring, 3,435 m elevation.

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EXECUTIVE SUMMARY

Surveys for the Peñasco least chipmunk (*Tamias minimus atristriatus*) occurred on public lands (Lincoln National Forest) during summer 2016 at four sites in the White Mountains (Lincoln Co.) and five sites in the Sacramento Mountains (Otero Co.). Three *T. m. atristriatus* were captured at two of four survey sites on and near Lookout Mountain in the White Mountains, Lincoln County. These captures represent new localities of record and provide the first verification of the taxon's persistence since 2000. Habitat at capture locations was the subalpine Thurber's fescue (*Festuca thurberi*) meadow biotic community type, which is different from prior records in the White Mountains and supports the hypothesis that *T. m. atristriatus* is associated with open, grassy sites. Development and recreational activities in the subalpine and alpine zone of the White Mountains may represent an ongoing negative impact on habitat for the species. Surveys at three areas in the Sacramento Mountains failed to document *T. m. atristriatus*, lending further evidence that this population may be extirpated. Well-developed, native grassy habitats were largely missing from this region. Additional studies are needed to determine population size and evaluate habitat selection of the White Mountain population of *T. m. atristriatus*. Results suggest that conservation of the White Mountain population of *T. m. atristriatus*, which may be the last remnant of the taxon, should focus on maintaining and enhancing subalpine Thurber's fescue meadow vegetation. In addition, further surveys and research on *T. m. atristriatus* in the White Mountains are warranted in order to better understand its distribution, ecological requirements, and threats.

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INTRODUCTION

The Peñasco least chipmunk (*Tamias minimus atristriatus*) is a morphologically and genetically distinct subspecies endemic to the Sacramento Mountains complex of Lincoln and Otero counties, New Mexico (Bailey 1913, Howell 1929, Conley 1970, Sullivan 1985, Sullivan and Petersen 1988). The state of New Mexico has listed this chipmunk as Endangered since 1983 and considers it a Species of Greatest Conservation Need (NMDGF 2016). In 2011, the US Fish and Wildlife Service (USFWS) was petitioned to list this chipmunk under the Endangered Species Act; in 2012 the USFWS determined that listing of the species was warranted but precluded and designated it a Candidate with high magnitude threats (USFWS 2012). Threats to the taxon include habitat alteration, drought, wildfire, and potential competition with the gray-footed chipmunk (*Tamias canipes*; NMDGF 2016, USFWS 2012).

Until recently, *T. m. atristriatus* was thought to occur at only two historically identified locations: James Canyon in the Sacramento Mountains (Otero Co.) and vicinity of Sierra Blanca Peak (Lincoln Co.; Frey and Boykin 2007). Habitat associations of chipmunks in these two locations were seemingly incongruous: those from James Canyon were ostensibly found in montane coniferous forests, while those from Sierra Blanca Peak were reported from rocky locations above tree line (Frey and Boykin 2007). In the early 1900's, this chipmunk was abundant in James Canyon (Bailey 1902, 1931). By the mid-1960s, the James Canyon population was rare and the last specimen was documented in 1966 (Conley 1970, Frey and Boykin 2007). Subsequent surveys in James Canyon and other areas of the Sacramento Mountains have failed to document persistence of this population (Hope and Frey 2000, Frey and Boykin 2007, Wampler et al. 2008). Conley (1970) reported "discovering" a new population of *T. m. atristriatus* on Sierra Blanca Peak. This population was subsequently documented as persisting during 1982 (Sullivan undated), 1998 (Ortiz 1999), and 2000 (Hope and Frey 2000). It has been more than 15 years since last documentation of *T. m. atristriatus* and its status is unknown.

Frey and Boykin (2007) undertook a comprehensive review of the status of *T. m. atristriatus* based on historical museum specimens and other documents. During that study, a large series of *T. m. atristriatus* collected in the 1930s from the White and Sacramento mountains but subsequently overlooked by the scientific community, was found in the Academy of Sciences of Philadelphia. Identifications were confirmed by Frey (2010). The specimens and other new information helped to unravel the mystery surrounding the historical distribution, habitat relationships, and possible reasons for decline of *T. m. atristriatus*, particularly with respect to the Sacramento Mountains population. Frey and Boykin (2007) concluded that unlike most other chipmunks (such as the sympatric *T. canipes*), *T. m. atristriatus* was associated with open grassy habitats interspersed with large cover structures, such as boulders or downed logs. In the Sacramento Mountains, *T. m. atristriatus* was historically widespread throughout mature, open ponderosa pine forest savanna and adjacent valley meadows, habitat types that have declined due to historical logging, fire suppression, livestock grazing, wildfire, development, and other causes. Based on the new findings, Frey and Boykin (2007) concluded that most prior chipmunk surveys and other small mammal studies in the Sacramento Mountains (e.g., Hope and Frey 2000, Ward 2001, Wampler

et al. 2008) were largely conducted in habitat types unsuitable for *T. m. atristriatus*; most surveys were instead conducted within the preferred habitat of *T. canipes*.

The purpose of the current study was two-fold. Our first goal was to determine if *T. m. atristriatus* was extant. The last place the species was documented was Buck Mountain, a lower outlying peak in the Sierra Blanca complex of the White Mountains (Figure 1). Here, one *T. m. atristriatus* was captured in July 1998 (Ortiz et al. 1998, Ortiz 1999) and two were captured in August 2000 (Hope and Frey 2000; Figure 1). However, surveys of the same area in 2007 by Frey and Boykin (2007) and 2015 by Hays (2015) failed to confirm presence of *T. m. atristriatus*. Therefore, we focused 2016 surveys on Lookout Mountain, which appeared to offer the best opportunity for capturing *T. m. atristriatus*. The second goal of our study was to use the newly gained knowledge about habitat relationships of *T. m. atristriatus* described by Frey and Boykin (2007) to conduct surveys in areas with potentially suitable habitat in the Sacramento Mountains. This study therefore has critically important ramifications for the conservation and management of this rare and endemic chipmunk in New Mexico.

STUDY AREA

White Mountains

The Sacramento Mountains Complex is composed of two distinct subranges: the White Mountains in the north and the Sacramento Mountains in the south, roughly divided by US Highway 82 (Figure 2; Julyan 2006). The White Mountains are of volcanic origin, include the highest elevations in the region, and dominate the landscape of much of south-central New Mexico. The highest peak is Sierra Blanca at 11,973 feet (ft; 3,649 meters [m]) elevation. Sierra Blanca was the southernmost location in the US to have a glacier during the Wisconsin glacial period, which carved a cirque on the northeast face (Richmond 1964). Sierra Blanca and other high peaks in the White Mountains are the southernmost representations of both alpine and subalpine biotic communities in the US. The alpine (tundra) zone is a cold, dry environment where vegetation consists of a relatively depauperate fellfield community dominated by cushion plants (Dick-Peddie 1993). No published papers have critically evaluated alpine plant communities in the White Mountains. The subalpine zone, which generally occurs above 9,800 ft (2,980 m) but is highly influenced by aspect, consists of two distinct biotic communities: spruce-fir forest and meadow/grassland. Subalpine coniferous forest (i.e., spruce-fir forest) is dominated by corkbark fir (*Abies lasiocarpa* var. *arizonica*) and Engelmann spruce (*Picea engelmannii*), which define this forest type, although Douglas-fir (*Pseudotsuga menziesii*) mixes into stands at the lower boundary or on relatively arid sites (Dye and Moir 1977, Dyer and Moffett 1999). The understory has high cover of herbs and shrubs, except in stands with Douglas-fir (Dye and Moir 1977). Although spruce-fir forest appears similar to lower elevation, mixed conifer forest (also called upper montane coniferous forest) in that both are dominated by conifer trees, spruce-fir forest is a highly distinctive and isolated community that displays little overlap in vegetative constituents with lower elevation, mixed conifer forest (Dye and Moir 1977; Dick-Peddie 1993). Lastly, above tree line and within openings in the spruce-fir forest are abrupt transitions to tall bunchgrass communities referred to as subalpine Thurber's fescue [*Festuca thurberi*])meadow (Moir 1967; Dick-Peddie

1993). Besides Thurber's fescue, these meadows are diverse and include other perennial bunchgrasses, sedges, a high proportion of flowering forbs (up to 35% of cover), and occasional shrubs, such as orange gooseberry (*Ribes pinetorum*) and mountain snowberry *(Symphoricarpos oreophilus*; Moir 1967). Some sources distinguish subalpine meadows on more mesic sites from subalpine grasslands on drier sites (e.g., USGS GAP Analysis Program), although no published studies have evaluated such distinctions in the White Mountains. The Thurber's fescue meadow biotic community is considered a climax subalpine community rather, than a seral stage of the spruce-fir forest, and is distinct from lower elevation, montane meadow grassland communities within the mixed conifer and ponderosa pine forest zones (Dyer and Moffett 1999; Dick-Peddie 1993).

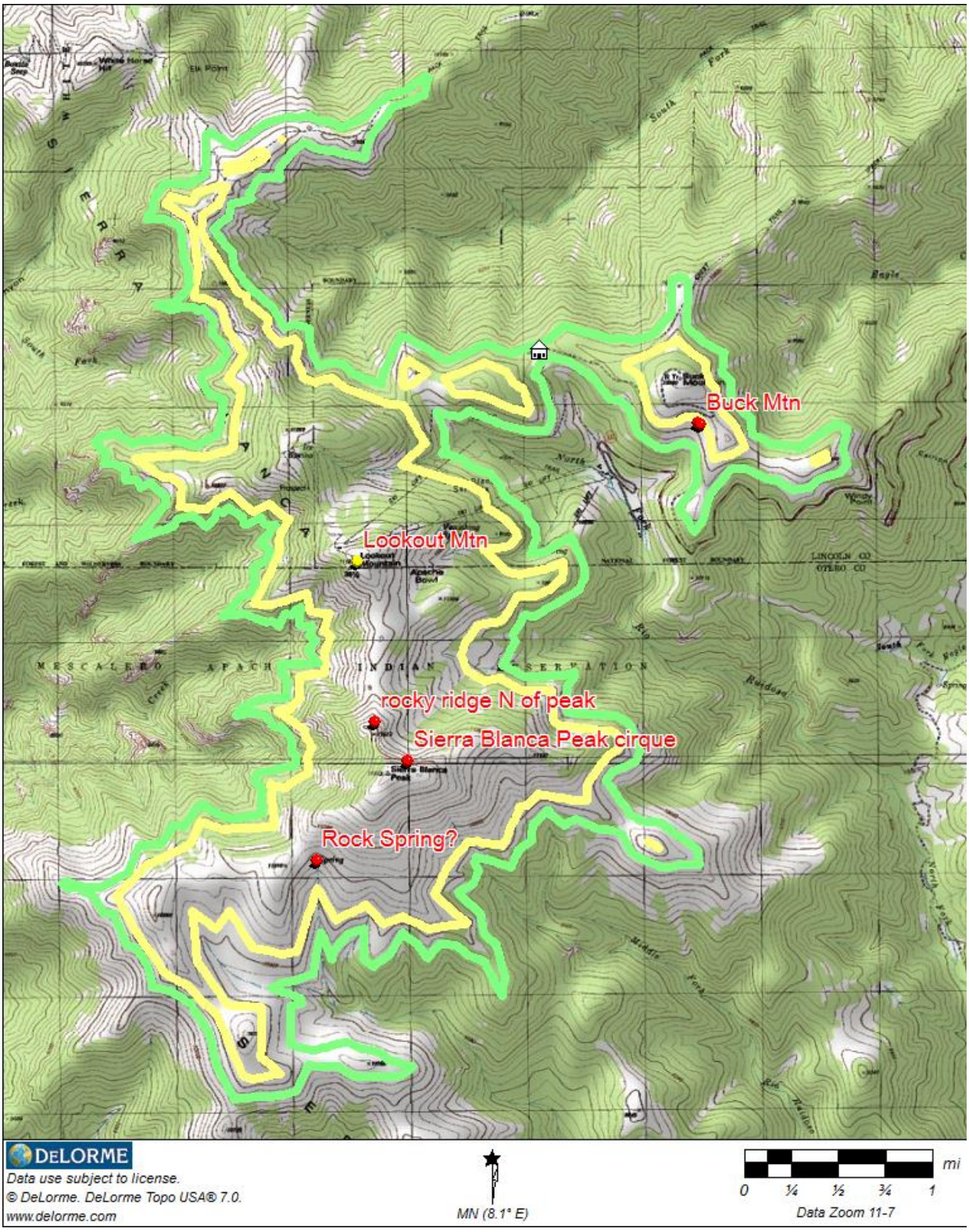

Figure 1. Range of the Peñasco least chipmunk (*Tamias minimus atristriatus*) in the White Mountains. Historical locations of record are indicated by red dots (see Frey and Boykin 2007). Location of 'Rock Spring' is uncertain (indicated by ?).

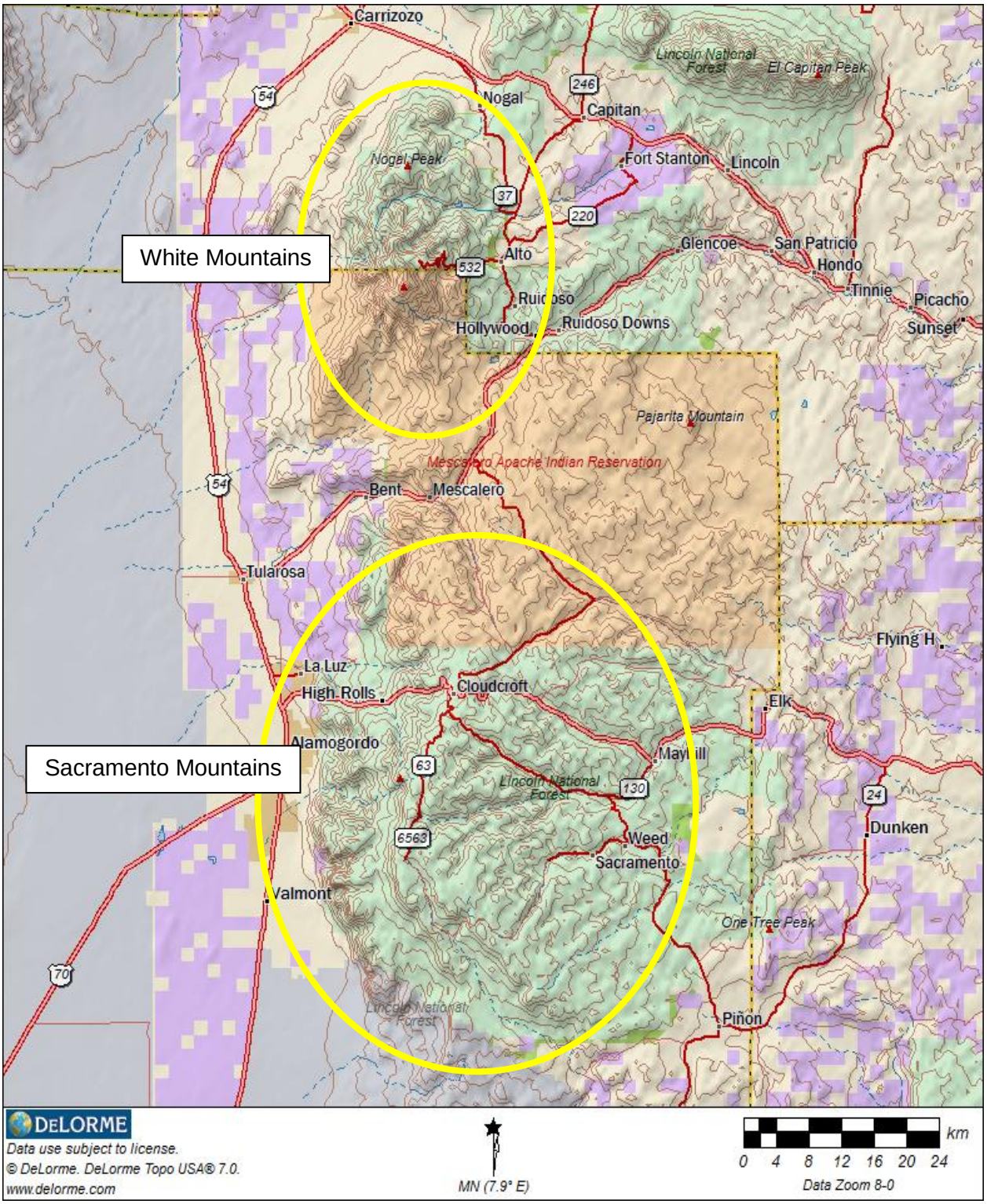

Figure 2. The Sacramento Mountains complex comprises two distinct subranges: the White Mountains and Sacramento Mountains.

Sacramento Mountains

The Sacramento Mountains subrange formed due to subsidence of the Tularosa Basin and the rising of adjacent blocks (Julyan 2006). This resulted in a relatively steep escarpment on the western aspect of the range and more gently sloping eastern aspects. Elevations at the crest of this subrange reach 9,245 ft (2,818 m) at Sacramento Peak. Given the slightly lower elevations of the Sacramento Mountains relative to the White Mountains, there is no alpine vegetation and the subalpine zone is restricted in distribution to a few eastern canyons near the crest, which consist of a depauperate, subalpine coniferous forest type dominated by Engelmann spruce and entirely lacking corkbark fir (Alexander et al. 1984). The most extensive forest type in the Sacramento Mountains is mixed conifer forest, which is also referred to as upper montane coniferous forest (i.e., in contrast to subalpine coniferous forest, sensu Dick-Peddie 1993). The mixed conifer forest occurs at higher elevations (>7,200 ft [2,195 m]) and is dominated by white fir (*Abies concolor*) or Douglas-fir, along with its seral species quaking aspen (*Populus tremuloides*), although it also contains blue spruce (*Picea pungens*), ponderosa pine (*Pinus ponderosa*) and several deciduous species (Alexander et al. 1984). The lower elevation forest type in the Sacramento Mountains is ponderosa pine forest, which also includes Gambel oak (*Quercus gambelii*) as a dominant species and is also called lower montane conifer forest (Alexander et al. 1984; Dick-Peddie 1993). Historically, this fire-tolerant forest type consisted of large mature trees distributed in a luxuriant grassland matrix, often described as a savanna (Dick-Peddie 1993). This forest type occurs at approximately 7,000 ft (2,134 m) elevation. Due to topography, ponderosa pine forest is not well represented on the Sacramento District of the Lincoln National Forest (i.e., it is better represented on the adjacent Mescalero Apache Reservation), and most of it has been significantly altered by land use practices (e.g., logging, grazing) and other disturbances (Alexander et al. 1985). Woodlands dominated by piñon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) occur below the ponderosa pine forest zone (Dick-Peddie 1993).

METHODS

Field Methods

Surveys for chipmunks were conducted using Sherman live-traps baited with commercial sweet feed, as this method has proven efficient and effective during prior surveys. Because *T. m. atristriatus* goes into a seasonal torpor (similar to hibernation), surveys occurred during late June – August; we verified above-ground chipmunk activity before beginning field work. In the White Mountains, cotton batting was added to traps to provide insulation for captured animals as the weather was cold, windy, and wet. Survey effort was calculated as “trap-day”, which was one trap set for at least part of one day. All animals captured were identified to species and released at capture locations with the exception of a single voucher specimen of each species of chipmunk (i.e., *T. canipes* and *T. m. atristriatus*) captured at a site. The gray-footed chipmunk (*T. canipes*) is sympatric with *T. m. atristriatus* and is very similar in appearance (Frey 2010). Misidentifications of these species during prior studies conducted by researchers who are not taxonomic experts have hampered knowledge about the conservation status and ecology of *T. m. atristriatus* (Frey and Boykin 2007). Voucher specimens provide the only incontrovertible and enduring evidence

of species occurrence, and voucher specimens have provided the only reliable information about the distribution and ecology of *T. m. atristriatus* (Frey and Boykin 2007). Consequently, all additional chipmunks captured were identified via careful examination and morphological measurement and released at their capture locations. Surveys were conducted under New Mexico Department of Game and Fish (NMDGF) scientific collecting permits issued to J.K. Frey (# 2868) and Q. R. Hays (# 3464).

Logistics for conducting surveys in the White Mountains were difficult and required considerable assistance from both Lincoln National Forest personnel and the Mescalero Apache Tribe. A successful survey effort in 2016 would have been impossible without this support. Lookout Mountain is near the top of the year-round gondola that serves recreational activities and support staff at Ski Apache, which is owned and operated by the Mescalero Apache Tribe. Ski Apache is located mostly on lands leased by the Lincoln National Forest (Figure 3). The ski area is developed with extensive infrastructure and receives heavy recreational use during both winter (e.g., skiing) and summer (e.g., gondola rides, mountain biking, zip line). The ski area base is located at 9,750 ft (2,972 m) elevation, while the summit of Lookout Mountain peak is 11,580 ft (3,530 m) in elevation. Access to the Lookout Mountain area was possible using a four-wheel drive vehicle (but only prior to 09:00 and after 17:00 as access roads also serve as mountain bike trails), or the gondola, but only after 09:00 and during good weather; gondola operations can suddenly cease due to lightning or heavy winds. Other logistical considerations included inclement weather during the onset of the Southwest monsoon (e.g., lightning and storm activity, but also reduced chipmunk activity and higher mortality rates during storms), and the high elevation of the survey sites, which reduced capacity for field crews to carry heavy equipment and travel expeditiously. Ski Apache staff granted permission for use of the gondola to transport equipment and people to the top of Lookout Mountain. They also provided handheld radios for communication with ski area support staff that allowed for advance notice of impending weather concerns. Lincoln National Forest staff granted permission to camp along the Lookout Mountain Trail (T78), and provided a Utility Task Vehicle to transport traps while conducting fieldwork in the White Mountains.

Geographic Information System (GIS) Habitat Model

To help inform decision-making on locations to survey for *T. m. atristriatus* in the Sacramento Mountains subdivision of the Sacramento Mountains Complex, Frey developed a GIS model of potential habitat for *T. m. atristriatus*. Because of topo-edaphic variation on the east versus west slope of the mountains, information was subdivided by watershed (i.e., Tularosa Watershed and Pecos Watershed [includes Sacramento River]). Model criteria were based on information from Frey and Boykin (2007) including: 6,800-7,000 ft (2,073-2,134 m) elevation in the Tularosa watershed; 7,500-8,000 ft (2,286-2,438 m) core elevation (extreme range 7,000-8,300 ft [2,134-2,530 m]) in the Pecos watershed; Southern Rocky Mountain Ponderosa Pine Woodland biotic community and Southern Rocky Mountain montane grassland biotic community. Large patches of modeled potential habitat were visited during a field reconnaissance prior to survey effort to confirm presence of key habitat elements (e.g., mature trees, grassy understory, large woody debris) and to prioritize sites for surveys.

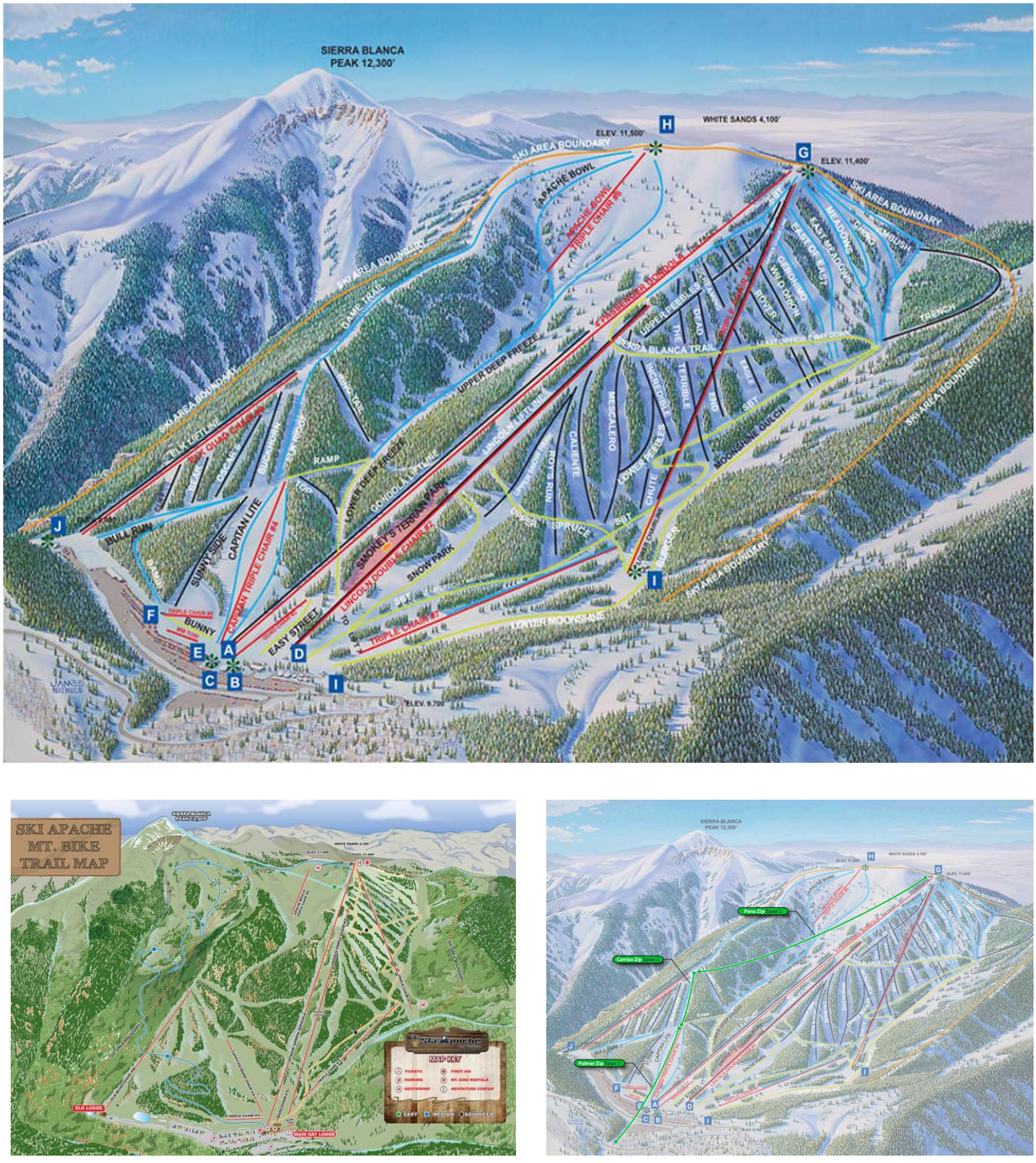

Figure 3. Ski Apache; most of the ski area is located on the Lincoln National Forest (LNF; boundary in orange). Lookout Mountain (G) and associated lifts/ski runs are located on LNF; the lift at Apache Bowl (H) and associated ski runs are on Mescalero lands. Bottom left shows mountain bike trails, bottom right shows new zip line. Taken from www.skiapache.com.

RESULTS

White Mountains

Surveys were conducted at four locations on and near Lookout Mountain 27 June – 1 July 2016 (Table 1; Figure 4). We focused on Lookout Mountain as the priority area for the surveys in the White Mountains for several reasons. The primary rationale was based on existing information about distribution and habitat of the White Mountain population of *T. m. atristriatus* (detailed in Frey and Boykin 2007), lack of access to Sierra Blanca due to land ownership, and other considerations including: 1) all historical records were at least 10,200 ft (3,109 m) elevation (Figure 1); 2) all historical records were located above tree line; 3) known historical habitat descriptions included talus or other rocks; 4) Lookout Mountain is located within the same large patch of subalpine meadow/tundra as that on Sierra Blanca Peak, which is considered the core population in the White Mountains (in contrast, Buck Mountain is a semi-isolated area of subalpine grassland that may have lost connectivity due to climate-mediated vegetation changes [Dyer and Moffett 1999]); 5) satellite imagery indicated presence of rocky habitat above tree line; 6) higher elevations of Ski Apache were not directly impacted by the 2012 Little Bear Fire; 7) least chipmunks are often associated with "open" habitats near escape cover; 8) *T. m. atristriatus* may be excluded from closed canopy woodlands and forests by competition with the larger *T. canipes*, which is a typical "forest chipmunk"; and 9) in Colorado, *T. minimus* was more abundant on ski runs and in powerline right-of-ways than in adjacent subalpine forest (Hadley and Wilson 2004a, b; Storm and Choate 2012). Furthermore, no *T. m atristriatus* were captured during the two most recent survey efforts (2007 and 2015) on Buck Mountain, which was the last location the species was documented (2002), and much of the vegetation on Buck Mountain burned during the 2012 Little Bear Fire.

Lookout Mountain Trail

This survey location was on the southwest-facing grassy slope and forest edge along the Lookout Mountain Trail (T78) above "Prospect" (location on USGS 1:24,000 map) and southwest of Ice Spring. Traps were set in the grassy meadow on the southwest-facing slope and along or immediately adjacent to tree line 27-29 June 2016 (ca. 400 trap-days; Figure 5). A single female *T. m. atristriatus* was captured 29 June 2016 at a small rock cairn along the trail, approximately midway into the grassland from the north (Figure 6, Table 2, 3). Other species captured at this site included *T. canipes* (at forest edge), North American deermouse (*Peromyscus maniculatus*), long-tailed vole (*Microtus longicaudus*), and Mogollon vole (*M. mogollonensis*; Table 2).

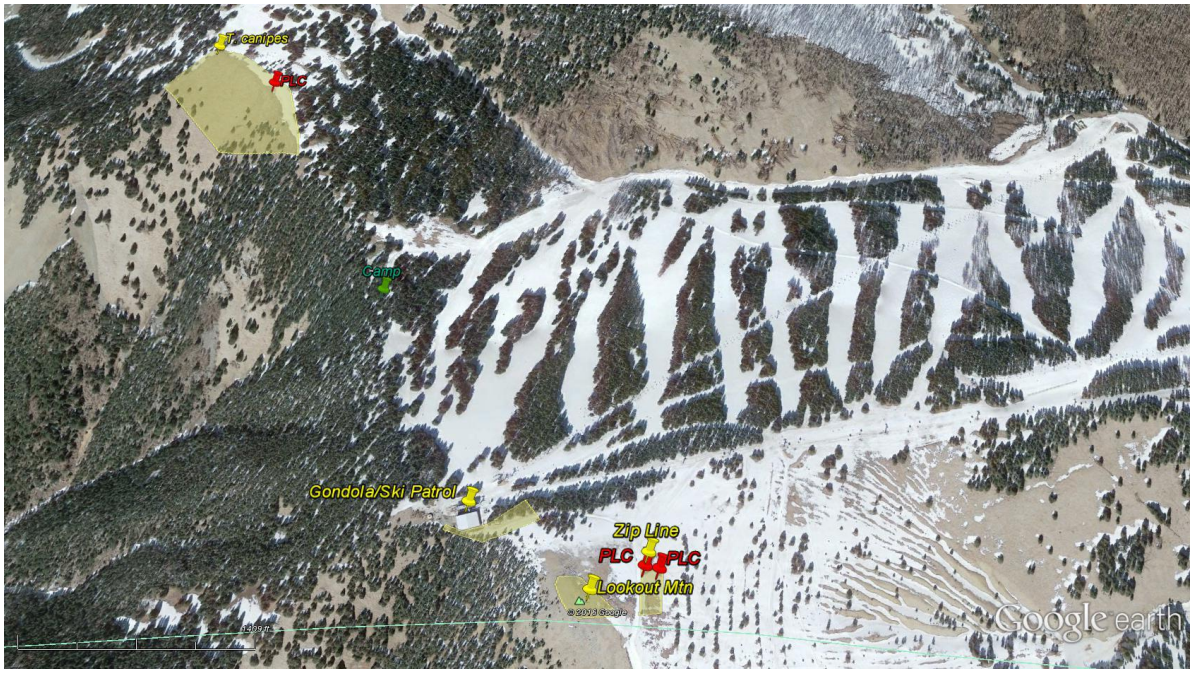

Figure 4. Landmarks, survey sites (yellow shading), and capture locations (red pins) for the Peñasco least chipmunk *(Tamias minimus atristriatus*) on Lookout Mountain, Lincoln National Forest, 27-30 June 2016.

Table 1. Locations and effort during surveys for the Peñasco least chipmunk (*Tamias minimus atristriatus*), 2016.

Range	County	Descriptive Location	Latitude	Longitude	Elevation (m)	Biotic Community	Dates	Trap-days
White	Lincoln	1.0 km NW Lookout Mountain, Trail T78 SW Ice Spring	33.397842	-105.81766	3435	subalpine meadow and edge spruce-fir forest	27-29 June 2016	400
White	Lincoln	Lookout Mountain, Ski Apache Gondola/Ski Patrol Base	33.391293	-105.813231	3473	disturbed area along edge spruce-fir forest	28-29 June 2016	80
White	Lincoln	Lookout Mountain Summit, southwest-facing slope (alpine fellfield)	33.390516	-105.811741	3514	alpine fellfield	28-30 June 2016	200
White	Lincoln	Lookout Mountain Summit, east-facing slope (subalpine meadow)	33.390852	-105.810689	3499	subalpine meadow	28-30 June 2016	200
Sacramento	Otero	James Canyon, NE of US Hwy 82 from James Canyon Campground; 1.8 km N, 2.3 km W Mayhill	32.905077	-105.503169	1975	ponderosa pine forest (oak shrub post-fire seral stage)	14-16 July 2016	974
Sacramento	Otero	Sixteen Springs Canyon, jct Co. Rd C9 and FS Rd 607; 10.5 km N Mayhill	32.982675	-105.483119	2116	ponderosa pine forest	16-17 July 2016	960
Sacramento	Otero	Seep Canyon, upper; 3.0 km S, 4.3 km W Weed	32.775371	-105.5637	2245	lower edge mixed coniferous forest	26-28 August 2016	480
Sacramento	Otero	Seep Canyon, middle; 2.6 km S, 2.2 km W Weed	32.779212	-105.540246	2228	ponderosa pine forest	26-28 August 2016	420
Sacramento	Otero	Seep Canyon, lower; 2.9 km S, 1.7 km W Weed	32.776293	-105.535343	2193	ponderosa pine forest (juniper post-fire seral stage)	26-28 August 2016	60

Table 2. Locations and capture results during surveys for the Peñasco least chipmunk (*Tamias minimus atristriatus*), 2016.

Range	County	Descriptive Location	Latitude	Longitude	Elevation (m)	*T. minimus*	*T. canipes*	*Microtus longicaudus*	*Microtus mogollonensis*	*Neotoma mexicana*	*Peromyscus boylii/nasutus*	*Peromyscus maniculatus*	*Reithrodontomys megalotis*
White	Lincoln	1.0 km NW Lookout Mountain, Trail T78 SW Ice Spring	33.397842	-105.817660	3435	1	2	7	4	0	0	23	0
White	Lincoln	Lookout Mountain, Ski Apache Gondola/Ski Patrol Base	33.391293	-105.813231	3473	0	4	0	0	0	0	0	0
White	Lincoln	Lookout Mountain Summit, southwest-facing slope (alpine fellfield)	33.390516	-105.811741	3514	0	1	0	0	0	0	5	0
White	Lincoln	Lookout Mountain Summit, east-facing slope (subalpine meadow)	33.390852	-105.810689	3499	2	0	4	2	0	0	14	0
Sacramento	Otero	James Canyon, NE of US Hwy 82 from James Canyon Campground; 1.8 km N, 2.3 km W Mayhill	32.905077	-105.503169	1975	0	0	0	0	0	11	4	1
Sacramento	Otero	Sixteen Springs Canyon, jct Co. Rd C9 and FS Rd 607; 10.5 km N Mayhill	32.982675	-105.483119	2116	0	1	0	1	0	0	6	0
Sacramento	Otero	Seep Canyon, upper; 3.0 km S, 4.3 km W Weed	32.775371	-105.563700	2245	0	4	0	13	4	0	26	0
Sacramento	Otero	Seep Canyon, middle; 2.6 km S, 2.2 km W Weed	32.779212	-105.540246	2228	0	0	1	9	3	8	24	0
Sacramento	Otero	Seep Canyon, lower; 2.9 km S, 1.7 km W Weed	32.776293	-105.535343	2193	0	0	0	8	0	0	6	1

Table 3. Locations, habitat, date, and sex of Peñasco least chipmunks (*Tamias minimus atristriatus*) captured in 2016.

Range	County	Descriptive Location	Northing	Easting	Habitat	Date	Sex
White	Lincoln	1.0 km NW Lookout Mountain, Trail T78 SW Ice Spring	424005	3695666	subalpine meadow	29-Jun	female
White	Lincoln	Lookout Mountain Summit, east-facing slope	424594	3694882	subalpine meadow	29-Jun	female
White	Lincoln	Lookout Mountain Summit, east-facing slope	424619	3694882	subalpine meadow	30-Jun	female

Figure 5. Survey location on Lookout Mountain Trail (T78) ca. 250 m southwest of Ice Spring. Trail 78 follows the crest of the hill. Top photo shows the southwest face, which was dominated by grass with interspersed rocks and currant (*Ribes* sp.). A Peñasco least chipmunk (*Tamias minimus atristriatus*) was captured on 29 June 2016 at the base of a small rock cairn (see Figure 6) in the grassland approximately midway along the trail in the open habitat. A gray-footed chipmunk (*T. canipes*) was captured along the forest edge at the top of the hill on 28 June 2016. Bottom photo provides survey and capture location context.

Figure 6. Capture location of a Peñasco least chipmunk (*Tamias minimus atristriatus*) on 29 June 2016, on Lookout Mountain Trail (T78) ca. 250 m southwest of Ice Spring. Top photo shows rock cairn near which chipmunk was caught, bottom photo shows meadow habitat looking north toward Ski Apache. Gray-footed chipmunks (*T. canipes*) were captured along the tree line on the left side of the bottom photo.

Gondola

This survey location was adjacent to the top of the Ski Apache gondola and associated ski patrol building immediately north of the summit of Lookout Mountain (Figure 7). Traps were set in association with rubble and road construction fill at the edge of the coniferous forest stand dominated by Engelmann spruce 28-29 June 2016 (80 trap-days; Figure 8). No *T. m. atristriatus* were captured at this location. The only captures at this site were *T. canipes*; no other species were recorded (Table 2). Chipmunk activity was observed on several occasions prior to and following survey effort at this location, but it seems likely that all were *T. canipes* due to capture results and available habitat in the area.

Lookout Mountain Summit Southwest

This survey location was on and around the south- and west-facing slopes near the summit of Lookout Mountain (Figure 7). Traps were set 28-30 June (200 trap-days). Habitat was primarily topo-edaphic fellfield alpine tundra (Dye and Moir 1977) with large rock outcrops (Figure 9). Vegetation was dominated by sparse, short, cushion-like alpine plants, especially forbs, many of which are recognized as USDA Forest Service sensitive species (O. Lucero personal communication; Roth undated). No *T. m. atristriatus* were captured at this survey location. Species captured included one *T. canipes*, as well as *P. maniculatus* and *M. longicaudus* (Table 2).

Lookout Mountain Summit East

This survey location was just below the Lookout Mountain access road (Figure 7) on an east-facing slope dominated by dense bunchgrass (subalpine Thurber's fescue meadow; Moir 1967; Dye and Moir 1977) with patches of currant (*Ribes* sp.; Figure 10). Two trap-lines were set at this location 28-30 June 2016 in order to sample slightly different habitats. One trap-line (ca. 80 trap-days) was situated along the downhill edge of the road where exposed rocks were scattered within the primary vegetation matrix of fescue and currant. The second trap-line (ca. 120 trap-days) was located parallel to the road transect but farther downhill, between the road and a disjunct tree line, where rocks were sparser. Although existing information suggests that *T. m. atristriatus* requires rocks, this trap-line served to test whether *T. m. atristriatus* could occur within habitat where tall grass and low shrubs provide escape cover rather than rocks (Figure 10). Two female *T. m. atristriatus* were captured at this survey location, one on each trap line and each in tall, dense ground cover vegetation (Figure 11). Other species captured included *P. maniculatus*, *M. longicaudus*, and *M. mogollonensis* (Table 2). Notably, this was the only site in the White Mountains where *T. canipes* was not captured.

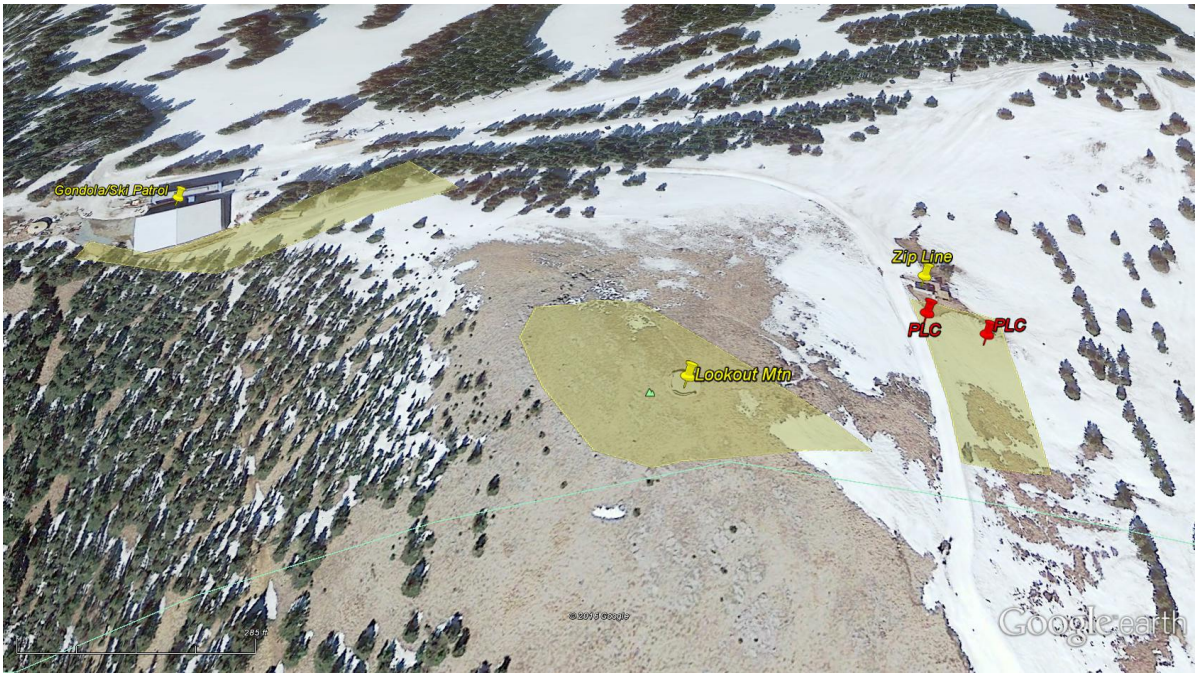

Figure 7. Survey locations (yellow shading) near peak of Lookout Mountain. The left polygon shows the survey site in the forest edge habitat around the developed gondola and ski patrol buildings; the center polygon shows the survey location on the south- and west-facing aspects of Lookout Mountain peak; the right polygon shows the survey location in the grassy, northeast-facing slope below the access road and next to the zip line. Capture locations for the Peñasco least chipmunk (*Tamias minimus atristriatus*) are indicated by red pins (only Gray-footed chipmunk [*T. canipes*] was captured at the Gondola and Lookout Mountain summit sites).

Figure 8. Four gray-footed chipmunks (*Tamias canipes*; inset) were captured among rocks in the disturbed forest edge habitat adjacent to the gondola and ski patrol buildings. The north face of Lookout Mountain peak is in the background on the left.

Figure 9. Survey site in fellfield alpine tundra on the southwest-facing slope of Lookout Mountain peak. A gray-footed chipmunk (*Tamias canipes*) was captured at this site.

Figure 10. Survey site along northeast side of Lookout Mountain peak below access road. Person is standing at a capture location of the Peñasco least chipmunk (*Tamias minimus atristriatus*) along the road-cut among rocks, currants (*Ribes* sp.), and bunchgrass (note the new zip line facility in the background). The dwarf tree near the capture location is Engelmann spruce (*Picea engelmannii*). Another least chipmunk was caught midway down the hill between the road and the forest edge in grass and currant (no rocks). No gray-footed chipmunks (*T. canipes*) were captured at this site.

Figure 11. Close-up of microhabitat where the Peñasco least chipmunk (*Tamias minimus atristriatus*) was captured along the access road near the new zip line facility at Lookout Mountain. Trap location is indicated by the flagging. Dominant vegetation are bunchgrasses and currant (*Ribes* sp.).

Sacramento Mountains

The GIS model indicated that landcover types with potentially suitable habitat for *T. m. atristriatus* were restricted in distribution and patchy (Figure 12). Areas currently mapped as montane grassland were particularly rare on the Lincoln National Forest. To further refine selection of sites for surveys, input from range and wildlife staff on the Sacramento Ranger District was incorporated into decision-making criteria and a site reconnaissance was conducted to prioritize surveys in areas that offered the best available habitat. However, we were unable to locate any area on the Sacramento Ranger District that appeared to provide suitable habitat for *T. m. atristriatus*. The causes of this altered habitat relative to historical conditions appeared to be related to livestock grazing (i.e., loss of native grassland and meadow; many areas now mostly bare ground with sparse wild tarragon and other invasive weeds), wildfire (i.e., invasion by dense thickets of Gambel oak or dense monotypic stands of weeping lovegrass [*Eragrostis curvula*], which was seeded during postfire erosion control efforts), or dense stands of young ponderosa pine (due to historical logging and other habitat modifications). Therefore, we selected three areas that offered some elements of habitat for *T. m. atristriatus* and that might have once been occupied habitat for the species (Figure 13).

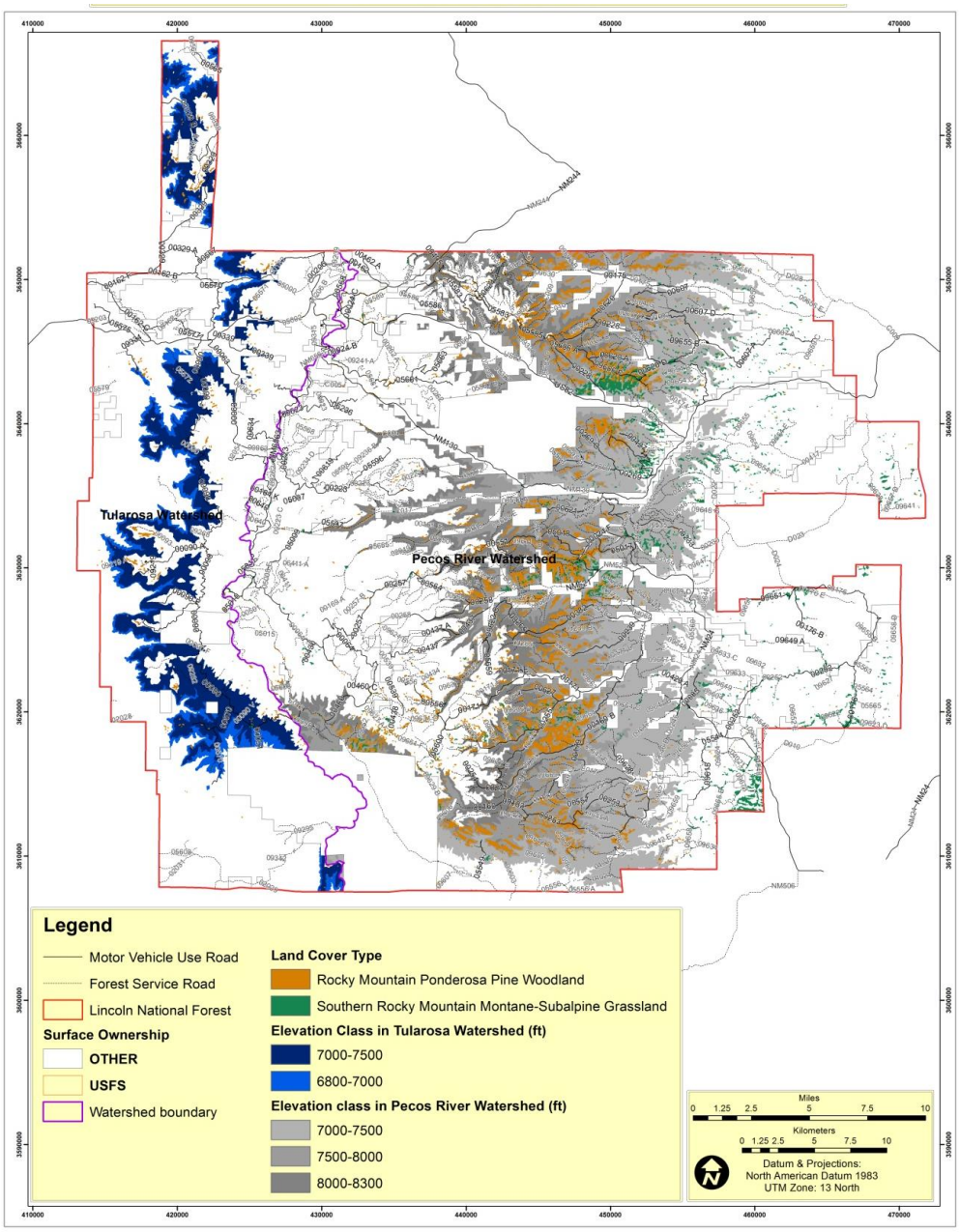

Figure 12. Map of potential habitat for the Peñasco least chipmunk (*Tamias minimus atristriatus*) on public lands in the Sacramento Mountains, Otero County, based on data in Frey and Boykin (2007). Suitable landcover types are in color (orange and green). Suitable elevations and in blue or gray: Tularosa watershed (6,800-7,000 ft [2,073-2,134 m]); Pecos watershed (primarily 7,500-8,000 ft [2,286-2,438 m], range 7,000-8,300 ft [2,134-2,530 m]). Private inholdings are removed from the map.

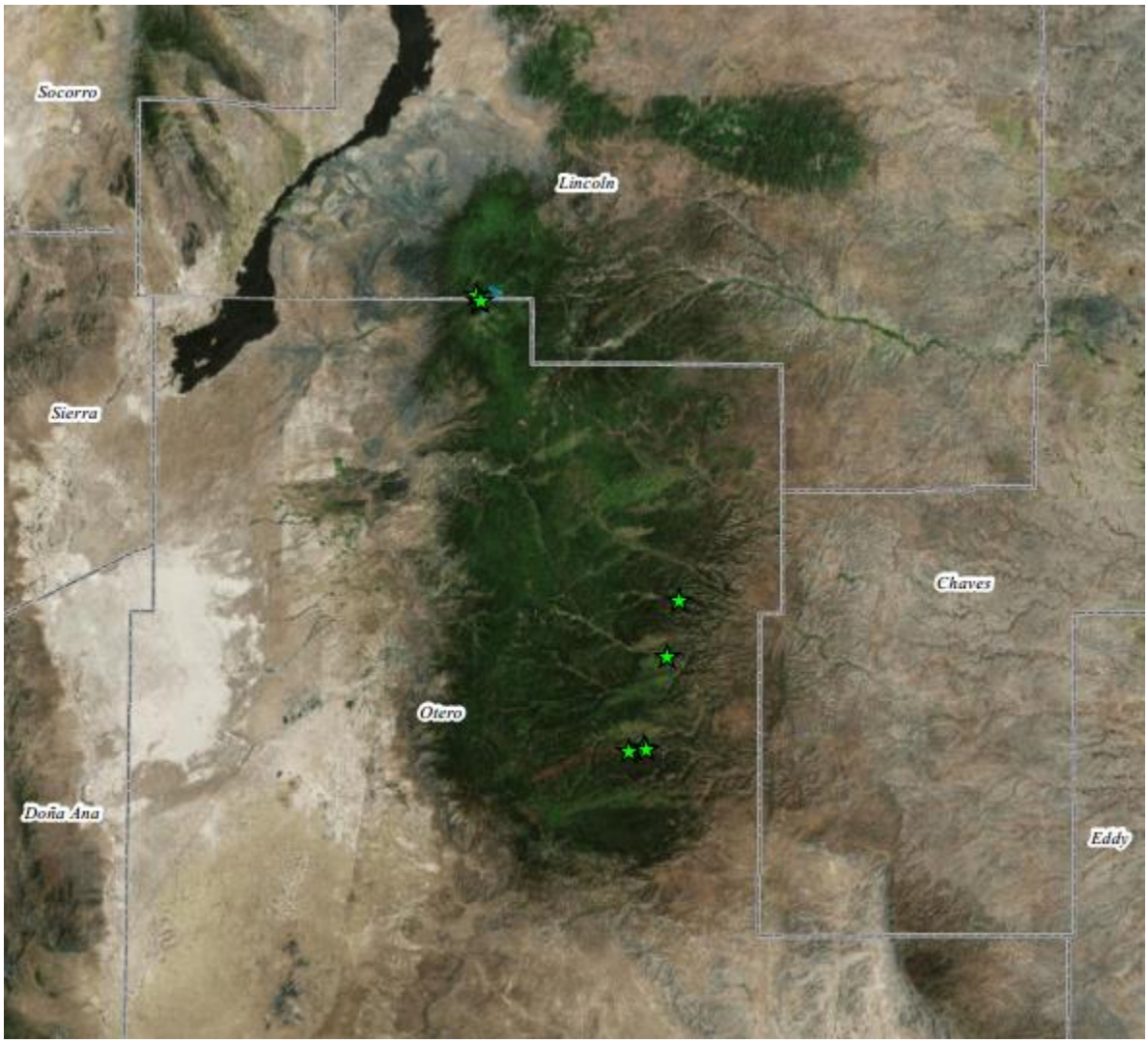

Figure 13. Survey locations for the Peñasco least chipmunk (*Tamias minimus atristriatus*) in the Sacramento Mountains, Otero County.

James Canyon

This survey took place in the last location (i.e., in 1966) where *T. m. atristriatus* was documented in the Sacramento Mountains, near the erosional gully in James Canyon adjacent to James Canyon Campground. Hope and Frey (2000) also surveyed this area, but focused on the gully, cliff face on the west side of the campground, and gully on the east side of the highway. The GIS model indicated that the area east of the highway was the largest patch of grassland in the Sacramento Ranger District. However, upon field inspection, grasses were limited to small patches (Figure 14). It was evident the area had formerly been a ponderosa pine forest, as there were standing dead trees that appeared to have been killed by wildfire. Most of the area was a dense thicket of shrub-form Gambel oak. We decided to survey this area because it was mapped as the largest patch of grassland, the species historically occurred in the vicinity, and, in some regions, *T. minimus* uses shrub-dominated habitats. This site was surveyed with 974 trap-days of effort; no chipmunks of either species were captured. Other species captured included *P. maniculatus*, brush deermouse (*P. boylii*), northern rock deermouse (*P. nasutus*), and western harvest mouse (*Reithrodontomys megalotis*; Table 2).

Figure 14. Survey location for the Peñasco least chipmunk (*Tamias minimus atristriatus*) in James Canyon, Sacramento Mountains, Otero County.

Sixteen Springs Canyon

Sixteen Springs Canyon was suggested by the Lincoln National Forest staff biologist as an area with mature ponderosa pine forest where habitat restoration efforts have occurred. The south-facing slope was a mature ponderosa pine forest that had been mechanically thinned; the north-facing slope was the lower boundary of mixed conifer forest (Figure 15). One north-facing slope was dominated by early-seral post-fire Gambel oak. However, this study area generally lacked a native, grassy ground cover, and consisted primarily of sparse grasses and forbs. This site was surveyed with 960 trap-days of effort. A single *T. canipes* was captured in the ponderosa pine forest near an arroyo (Table 2). Other species captured included four *P. maniculatus* and a single *M. mogollonensis*. The low overall abundance and diversity of small mammals, and near absence of voles, attests to the degraded habitat (i.e., loss of grassland) conditions at this site. Although the tree structure might be similar to historical conditions, the ground cover, which ultimately determines small mammal community composition and abundance, was almost completely lacking in the attributes necessary to sustain a diverse species assemblage.

Figure 15. Survey location for the Peñasco least chipmunk (*Tamias minimus atristriatus*) in Sixteen Springs Canyon, Sacramento Mountains, Otero County.

Seep Canyon

Seep Canyon was suggested by Lincoln National Forest staff as an area with a well-developed grassland habitat. We surveyed three sites within this canyon, which ranged from near the lower border of the ponderosa pine zone up (in elevation) to the lower border of mixed conifer forest. It appeared that the canyon was once dominated by ponderosa pine forest but wildfire had caused a seral shift, or possibly a type transition; ponderosa pine now only occurs in a few isolated stringers and patches. Overall habitat varied between areas with mostly bare ground and invasive weeds, areas with dense patches of Gambel oak with interspersed grasses and forbs, areas with ponderosa pine, and areas with tall, dense weeping lovegrass.

Lower Site

The lower surveyed site was in the valley bottom where there was tall grass, forbs, and down logs, which appeared ideally suited for chipmunks (Figure 16). However, no chipmunks were captured, although many other small mammals, including *M. mogollonensis*, *P. maniculatus*, and *R. megalotis*, were recorded (Table 2). Both *M. mogollonensis* and *R. megalotis* are indicative of well-developed grassland habitat.

Middle Site

The middle surveyed site was in a remnant stand of ponderosa pine with a ground cover consisting of dense patches of shrub-form Gambel oak or sparse grasses and forbs (Figure 16). No chipmunks of either species were captured at this site, although the overall small mammal community was diverse (although not particularly abundant) and included *M. longicaudus*, *M. mogollonensis*, Mexican wood rat (*Neotoma mexicana*), *P. boylii/nasutus*, and *P. maniculatus* (Table 2).

Upper Site

The upper surveyed site was at the point where ponderosa pine transitions to mixed conifer forest. Some areas of the forest were intact while others were in an early seral, postfire state (Figure 16). Three *T. canipes*, but no *T. m. atristriatus*, were captured at this site (Table 2). Two *T. canipes* were captured around downed logs within the burned forest habitat and one was captured in intact, mixed conifer forest. Other species captured included *M. mogollonensis*, *P. maniculatus*, and *N. mexicana*.

Figure 16. Survey locations for the Peñasco least chipmunk (*Tamias minimus atristriatus*) in upper (top photo), middle (middle photo), and lower (bottom photo) Seep Canyon, Sacramento Mountains, Otero County.

Reevaluation of Historical Buck Mountain Capture Locations

Considering the captures of *T. m. atristriatus* in the Thurber's fescue meadow biotic community on and near Lookout Mountain in 2016, we reevaluated the evidence surrounding the 1998 and 2000 captures of *T. m. atristriatus* on Buck Mountain. These occurred in the vicinity of a large talus slope on the southwest face of the mountain (Figure 17). Hope and Frey (2000) surveyed three habitats on Buck Mountain: "montane meadow" (200 trap-days), "open talus" (80 trap-days), and "forest talus" (120 trap-days). The two captures of *T. m. atristriatus* were reported from the "open talus" habitat, which was described as "patchy talus slope facing southwest from the top of Buck Mountain with a slope of 40°." (Hope and Frey 2000: 34). Further, they (Hope and Frey 2000: 34) reported that the two least chipmunks "both entered traps set on bare talus rock patches which were surrounded by grass meadow and some small, well dispersed Douglas-fir (*Pseudotsuga menziesii*), although the location was above the forest zone". The GPS location for the *T. m. atristriatus* captured in 1998 was reported incorrectly by Ortiz (1999), but based on photographs and other information, Frey and Boykin (2007) determined that the 1998 capture location was in the same vicinity as the 2000 captures reported by Frey and Hope (2000). The GPS locations of the two *T. m. atristriatus* captured in 2000 reveal that the animals were not caught within the talus fields per se, as implied by the reports (Figure 17). Rather, the capture locations were at the edge, between the subalpine meadow and small patches of talus (Figures 18-19).

Interestingly, no *T. m. atristriatus* (or *T. canipes*) were captured in the "montane meadow" habitat, despite a large trap effort in this habitat. This habitat was described as "situated both on top of Buck Mountain and on the south-facing slope near the summit with a slope from 1-40°. There was ~90% groundcover of grasses and also sparse forbs such as alpine lupine, wild onion, and mountain iris. The soil was very thin with talus rock underneath" (Hope and Frey 2000:34). In addition, no *T. canipes* were captured at the same survey locations where *T. m. atristriatus* was captured during either the 1998 (Ortiz et al 1998), 2000 (Hope and Frey 2007), or 2015 surveys (Hays 2015). However, *T. canipes* was captured at survey locations near or in forest, including talus bordering forest (Hope and Frey 2000; Frey and Boykin 2007; Hays 2015).

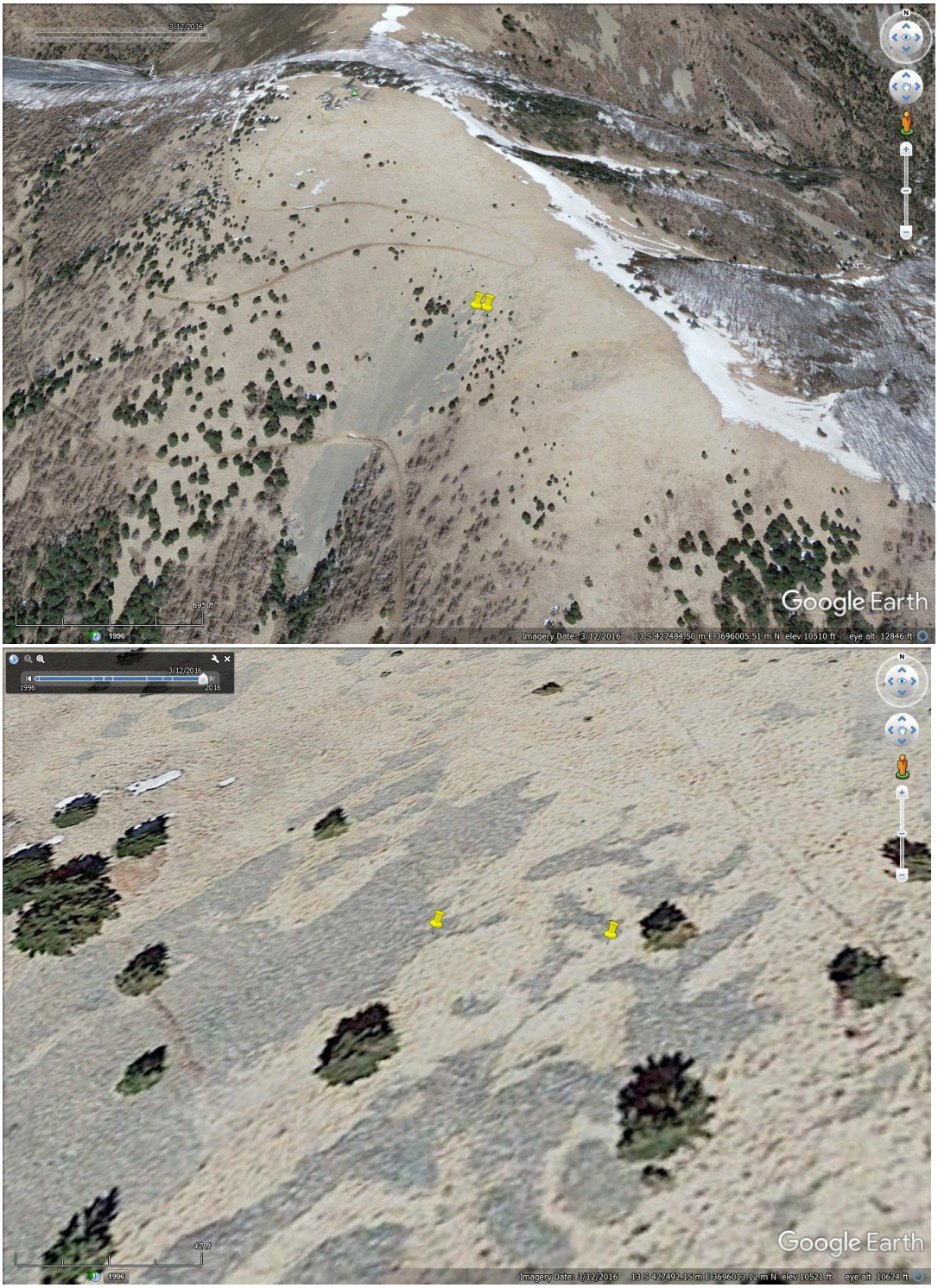

Figure 17. Capture locations (yellow pins; top, context; bottom, close-up) for two Peñasco least chipmunks (*Tamias mimimus atristriatus*) on Buck Mountain in 2000; these captures were in the same vicinity of a third capture in 1998 reported by Ortiz et al 1998 and Ortiz 1999 (Hope and Frey 2000). Both captures were in subalpine Thurber's fescue (*Festuca thurberi*) meadow biotic community (beige areas) at the edge of talus fields (gray areas).

Figure 18. Photograph taken during surveys in 2007 (Frey and Boykin 2007) showing capture locations of the two Peñasco least chipmunks (*Tamias minimus atristriatus*) captured on Buck Mountain, Lincoln County, in 2000 (Frey and Hope 2000). The people are standing at the two capture locations. Close-ups of each location are in Figure 19.

Figure 19. Photographs taken during surveys in 2007 (Frey and Boykin 2007) showing capture locations of the two Peñasco least chipmunks (*Tamias minimus atristriatus*) captured on Buck Mountain, Lincoln County, in 2000 (Frey and Hope 2000). The people are standing at the capture locations. An overview of both capture locations is shown in Figure 18.

DISCUSSION

Evidence from the capture locations of *T. m. atristriatus* on Lookout Mountain during this study, and Buck Mountain during prior studies, suggests that the White Mountains population of *T. m. atristriatus* is associated with the subalpine Thurber's fescue meadow biotic community and occurs locally where rocks are present. This habitat description is consistent with other studies in Colorado that have described *T. minimus* as abundant in well-drained, subalpine meadows (e.g., Carleton 1966; Vaughn 1974; Figure 20). Subalpine Thurber's fescue meadow is likely important for *T. m. atristriatus* for a variety of reasons. First, while typical "forest chipmunks" (e.g., *T. canipes*) are thought to be strongly reliant on conifer mast for food, the significantly smaller *T. minimus* can exploit small seeds from herbaceous plants to meet its energetic requirements (Bergstrom and Hoffman 1991). The diet niche breadth of *T. minimus* may be narrower than in some other ground squirrels, as they tend to strongly select particular plant species for food. Primary food sources include seeds and flowers of various forbs (especially composites [Asteraceae]), and certain arthropods (Carleton 1966; Vaughn 1974; Carey et al. 1980). An abundance of suitable forbs is critical to *T. minimus* because they depend on large caches (0.5-0.8 kg) of stored seeds during winter torpor. This strategy is different than that employed by hibernating small mammals in the Southwest, such as jumping mice (*Zapus* spp.), which rely solely on fat reserves during winter (Criddle 1943; Verts and Carraway 2001). Thus, subalpine meadows can provide the specialized dietary requirements for *T. minimus*.

Second, because *T. minimus* must forage in meadows to access forbs, bunchgrasses likely serve as important concealment cover from predators while the chipmunks are foraging. Bunchgrasses likely provide ideal conditions because they provide overhead cover while also providing clear travel and escape paths at ground level. In contrast, "forest chipmunks", such as *T. canipes*, often avoid predators by fleeing up trees. *T. minimus* forages more efficiently when cover provides a safe habitat, while larger species forage more efficiently in riskier habitat further from cover (Smith 1995). In this way, the smaller species may out-compete the larger species in safe habitats, while larger species out-compete smaller species in riskier habitat (Smith 1995). For *T. minimus*, safe foraging habitats appear to be those with dense herbaceous or low shrub ground cover, and those that include a rock component. Finally, *T. minimus* has relatively low water requirements and is able to tolerate higher temperatures than forest chipmunks, which may allow it to exploit the relatively drier and warmer (during summer months) conditions of open meadow communities (Heller and Poulson 1972).

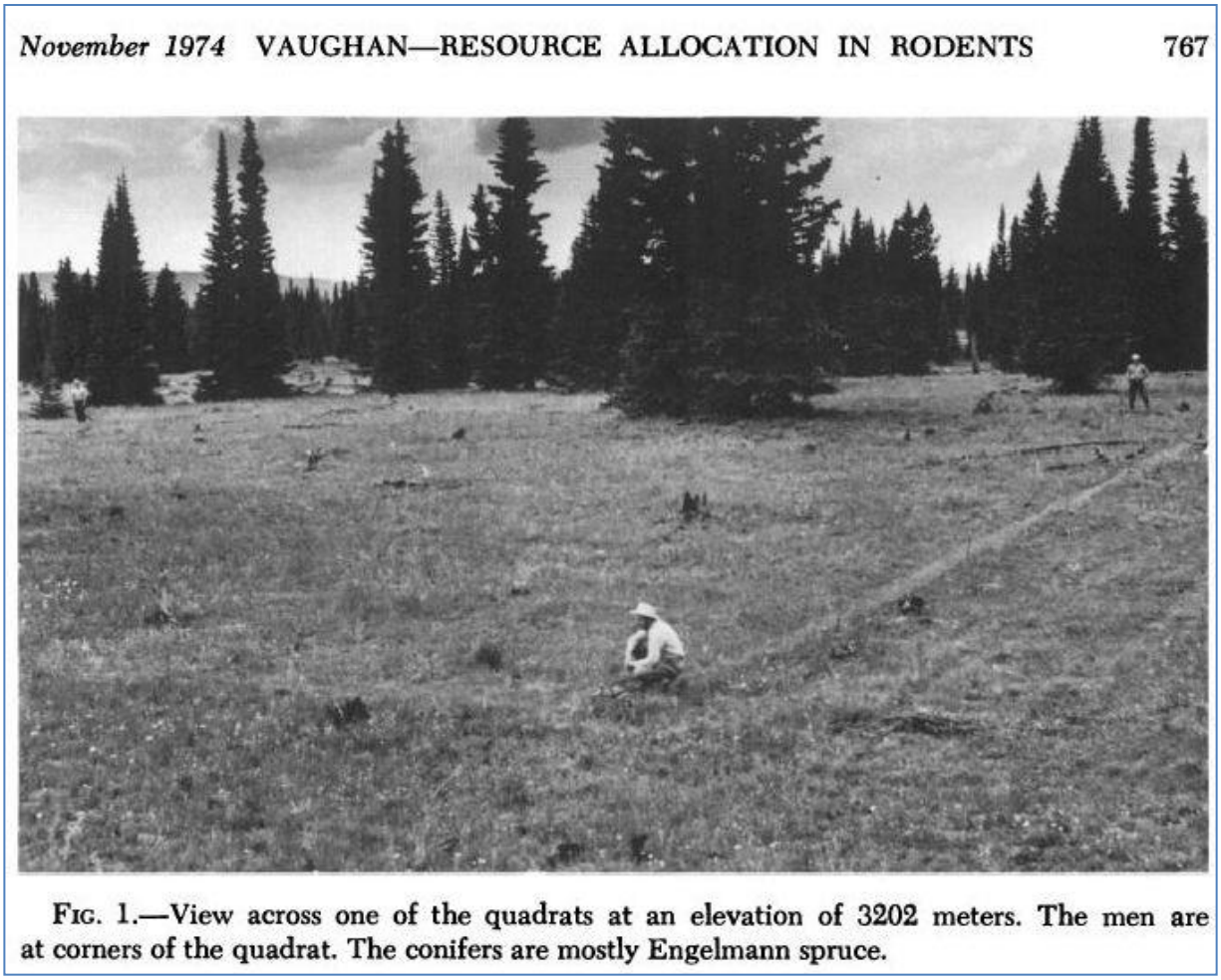

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FIG. 1.—View across one of the quadrats at an elevation of 3202 meters. The men are at corners of the quadrat. The conifers are mostly Engelmann spruce.

Figure 20. Example of a subalpine meadow habitat in Colorado where least chipmunks (*Tamias minimus*) are abundant. Least chipmunks occurred wherever stumps, rocks, or logs provided structure within the meadow. Figure is taken from Vaughn (1974).

The rock component of the habitat used by *T. m. atristriatus* in the White Mountains likely serves as cover for burrow opening and den sites, and as observation points for predator vigilance. *T. minimus* usually nests in burrows constructed underground (Criddle 1943; Laundré 1989, Bihr and Smith 1998). In subalpine meadows in Colorado, most (>75%) *T. minimus* burrow entrances were located under rocks of relatively large size (ca. 0.3-0.8 square meters [m^2]) compared to what was locally available (Bihr and Smith 1998). In another study in Colorado, the local occurrence of *T. minimus* within a subalpine meadow was tied to presence of some kind of prominent habitat structure: rocks, stumps, or large fallen limbs (Vaughn 1974). Vaughn (1974) concluded that *T. minimus* depended on the rocks and stumps for observation points and used logs and fallen branches when fleeing. Vaughn (1974) considered these structures critical and to define the center of activity for least chipmunks. Given that *T. minimus* is territorial (Bergstrom 1992), it seems likely that these structures form the center of home ranges, and the availability of such structures could be a limiting factor if they are sparse in otherwise suitable habitat. The use of rocks as observation structures likely accounts for Sullivan's (1985) conclusions that rocks were the key habitat component for the White Mountain population of *T. m. atristriatus*, as he measured habitat on 3-m radius plots at the specific locations where a chipmunk was trapped or first observed (if shot). Consequently, the relationship of *T. m. atristriatus* with adjacent vegetation types was not properly accounted for in that study.

The more refined description of key habitat for the White Mountain population of *T. m. atristriatus* suggests several important implications. First, the area of suitable habitat for *T. m. atristriatus* in the White Mountains is likely far less than previously conceived. Frey and Boykin (2007) created habitat suitability models for *T. m. atristriatus*, but their analyses were flawed by a poor understanding of relevant habitat associations for the species. For instance, their deductive models identified 75,888 hectares (ha) of potentially suitable habitat for *T. m. atristriatus* in the White Mountains, but that was based on identifying bedrock, cliff, and rock outcrop as primary habitat (31,106 ha), and subalpine forest and montane-subalpine grassland as secondary habitat (44,782 ha; Frey and Boykin 2007). In actuality only a fraction of one of those land cover types, the subalpine component of the montane-subalpine grassland, should be considered suitable. However, even then, it is likely that much of the subalpine grassland lacks proper microhabitat conditions (i.e., the presence of rock or talus) and is therefore likely to be unoccupied by *T. m. atristriatus*.

Since *T. m. atristriatus* is associated with herbaceous communities and studies in other regions have found a positive response by *T. minimus* to fire (Ellis et al 2008), some might posit that the Little Bear Fire, which burned much of the higher elevations of the White Mountains (Figure 21), may have increased habitat for the species. However, available research indicates that, in the White Mountains, subalpine meadow is not a seral stage of subalpine coniferous forest (Dye and Moir 1977; Dyer and Moffett 1999). Rather, following fire, the spruce-fir forest in this region usually regenerates through an herbaceous and shrub-thicket stage, then a sapling and pole-sized tree stage, before transitioning to relatively stable, mature forest (Dye and Moir 1977). The plant species occurring in the early stages of regeneration are constituents of mature forest, rather than Thurber's fescue meadow (Dye and Moir 1977). Therefore, it is unknown if early seral, post-fire habitat in the White Mountains could provide adequate resources for *T. m. atristriatus*.

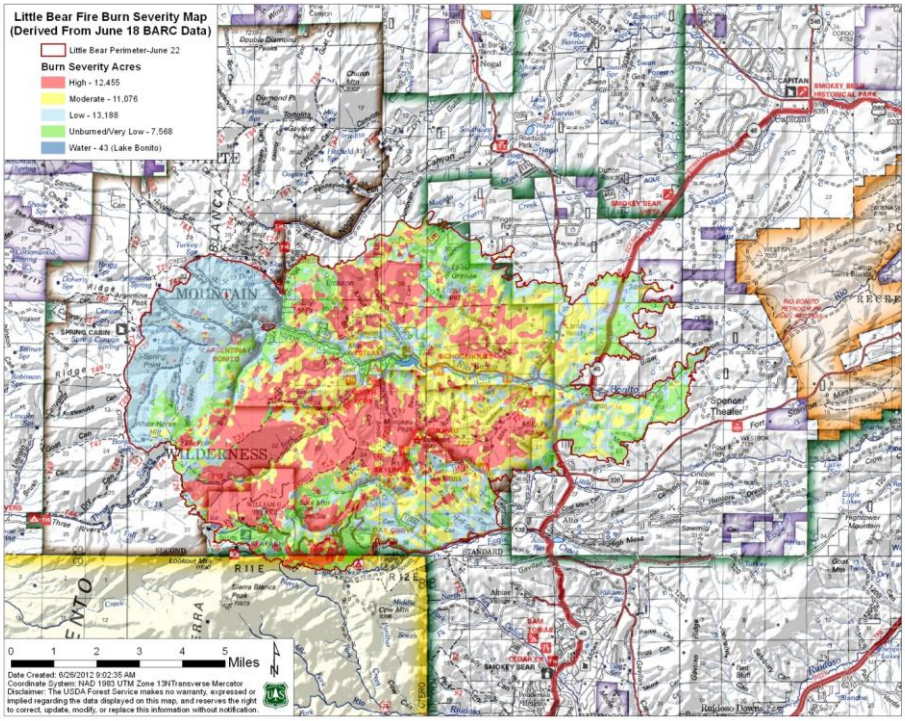


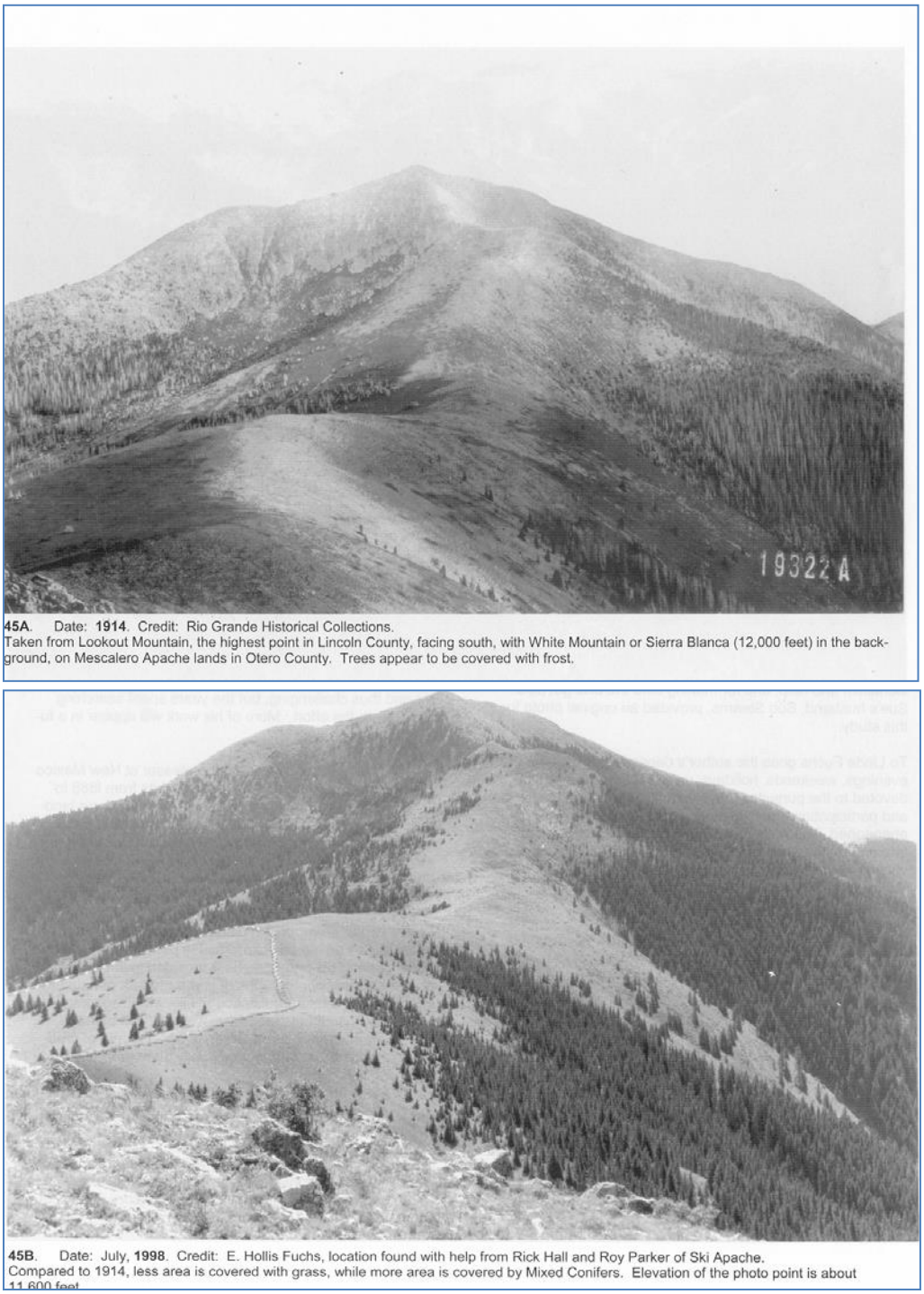
Figure 21. Burn severity map for the Little Bear Fire on 27 June 2012. Sierra Blanca Peak and Lookout Mountain are outside of the fire perimeter (thin red line); much of Buck Mountain experienced high severity burn. Taken from inciweb.nwcg.gov.

An exception might exist for spruce-fir stands that regenerate through an aspen (*Populus tremuloides*) seral stage and are adjacent to meadows as these often have an herbaceous understory that consists of many plant species that also occur in the adjacent Thurber's fescue meadows (Moir 1967). However, aspen is not common in the subalpine zone; it is primarily a constituent of a mixed conifer forest, which occurs at lower elevations (Dick-Peddie 1993). Further, spruce-fir forests in the White Mountains are dominated by a unique, long-lived variety of corkbark fir, some of which have been aged at >275 years (Dye and Moir 1977). Such stands are unlikely to regenerate through an aspen stage because aspen clones die out if closed canopy forest conditions have existed for >150 years (Dick-Peddie 1993). This might account for the dominance of regeneration through herb/shrub and sapling/pole seral stages, rather than an aspen stage, in this region. In the Jemez Mountains, *T. minimus* did not respond favorably to wildfire (Converse et al. 2008). Overall, it seems unlikely that the recent (2012) Little Bear Fire would have a positive impact on *T. m. atristriatus*, though this relationship requires additional research.

Thurber's fescue meadows can convert to other biotic communities through various forces. First, livestock grazing is thought to have resulted in the conversion of some stands of Thurber's fescue to Kentucky bluegrass (*Poa pratensis*) in the White Mountains (Moir 1967). Kentucky bluegrass stands have been found on lower, gentle slopes and valley bottoms, as well as along trails and recreation sites used by pack animals (Moir 1967). Studies have found that densities of *T. minimus* decline with grazing (Medin and Clary 1989). We could find no papers reporting *T. minimus* in Kentucky bluegrass meadows. Any historical or current conversion of native Thurber's fescue meadows to Kentucky bluegrass is likely to be detrimental to *T. m. atristriatus*. Second, like other areas in the Southwest, there has been an apparent invasion of conifer trees into grassland communities in the White Mountains (Fuchs 2001). For instance, historical photographs of Sierra Blanca clearly show the expansion of forest up-elevation into formerly treeless areas (Figure 22). Several factors have been implicated in tree invasion, including livestock grazing, shifting fire regimes, and climate change. In the White Mountains, Dyer and Moffet (1999) determined that the invasion of conifers into Thurber's fescue meadows has occurred continuously since the 1930s and concluded that it likely was primarily the result of climate change, specifically peaks in precipitation in conjunction with warmer temperatures. Projected future climate in the Southwest will likely bring increasing temperatures, as well as more variable moisture patterns, which could continue to drive a loss of Thurber's fescue meadows.

Frey and Boykin (2007) compiled all available information on the status of *T. m. atristriatus* in the Sacramento Mountains subrange. They determined that, while many surveys and field studies in that region had targeted inappropriate habitat (i.e., mixed conifer forest), evidence indicated there had been a long-term decline in the population and that the species could no longer be found at some sites where it had formerly occurred, despite surveys at those sites during the 1970s, 1980s, and 2000s. The last documented occurrence of *T. m. atristriatus* in the Sacramento Mountains was in 1966 (Frey and Boykin 2007). Our study aimed to find and survey any areas with potential habitat based on new information provided by Frey and Boykin (2007). However, GIS determination of potential land cover suitable for *T. m. atristriatus* in the Sacramento Mountains showed that montane grasslands and ponderosa pine forests were restricted in distribution. None

of the areas we visited in the field appeared to have appropriate habitat for *T. m. atristriatus*, as all lacked well-developed, native meadow and grassland vegetation communities. Vegetation showed deleterious effects of long-term livestock grazing, wildfire, and logging, and generally consisted of either high percentage bare ground with sparse forbs, monotypic stands of tall weeping lovegrass, dense oak shrub, or dense, regenerating ponderosa pine, none of which are suitable for *T. m. atristriatus*. It was not surprising that we were unable to document *T. m. atristriatus* in the Sacramento Mountains. These findings add further evidence to support the conclusion that the Sacramento Mountains population of *T. m. atristriatus* may be extinct, at least on public lands (Frey and Boykin 2007). However, we have observed some areas on private and tribal lands that may retain suitable habitat conditions. It remains a possibility that undetected populations persist.



45A. Date: **1914**. Credit: Rio Grande Historical Collections.
Taken from Lookout Mountain, the highest point in Lincoln County, facing south, with White Mountain or Sierra Blanca (12,000 feet) in the background, on Mescalero Apache lands in Otero County. Trees appear to be covered with frost.

45B. Date: July, **1998**. Credit: E. Hollis Fuchs, location found with help from Rick Hall and Roy Parker of Ski Apache.
Compared to 1914, less area is covered with grass, while more area is covered by Mixed Conifers. Elevation of the photo point is about 11,600 feet.

Figure 22. View from Lookout Mountain facing south to Sierra Blanca in 1914 (top) and 1998 (bottom) (Photos taken from UHWC 2004). Note expansion of coniferous forest and loss of herbaceous communities above tree line from 1914 to 2004.

MANAGEMENT RECOMMENDATIONS

Our findings provide evidence that *T. m. atristriatus* persists in the White Mountains. However, our results also suggest that in these mountains, the taxon is restricted to the subalpine Thurber's fescue meadow biotic community where rocks are present. Thus, this relict population may be much smaller than previously considered. Further, we identified a variety of factors that have caused historical, and likely ongoing, loss of this habitat. This habitat loss is potentially contributing to a continuing decline of this species. Management recommendations based on the findings of this study include:

1. Disturbance of Thurber's fescue meadow should be avoided and efforts should be made to restore this habitat. Of particular concern are recreation and development that may cause direct loss of habitat or other forces leading to indirect habitat loss through erosion, tree encroachment, or conversion to Kentucky bluegrass meadows.

2. Scientifically defensible research is needed to test predictions derived from our hypotheses about key habitat requirements for the White Mountain population of *T. m. atristriatus*. Such studies should be carefully developed and rigorously implemented in order to determine habitat requirements, distribution and population size, population connectivity, response to disturbance (e.g., fire, recreation, ski infrastructure, climate change), and interactions with *T. canipes*. In particular, research should consider that *T. m. atristriatus* might exist as a series of isolated populations or a metapopulation linked by dispersal corridors of various suitability.

3. Research is needed to determine if the Thurber's fescue meadow biotic community can be restored in areas that have been disturbed, such as ski slopes. Such efforts should include evaluating the efficacy of adding scattered large rocks to provide necessary structure for core home range use by *T. m. atristriatus*. Prior research on modifying ski slopes to aid wildlife included addition of rows of logs (Hadley and Wilson 2004a, b). However, those methods resulted in depressed abundances of *T. minimus*, possibly because wood piles were also attractive to other small mammals, which may be competitively dominant or predators of *T. minimus*. Thus, addition of large amounts of woody debris in meadows is not recommended. In addition, restoration efforts should evaluate efficacy of removing encroaching conifer trees from meadows. We also do not recommend planting trees within the Thurber's fescue meadow systems. There are rows of conifers that appear to have been planted on the east-facing slope of Lookout Mountain immediately below where *T. m. atristriatus* was captured in 2016. We recommend that plants native to the Thurber's fescue meadow biotic community be used to control erosion rather than trees, and we recommend removal of these trees if possible and where practicable. However, stumps and a few felled logs (but not the slash) should be left behind after tree removal.

4. *T. minimus* is prone to extreme annual population fluctuations that can result in local extirpation (Bartel et al. 2008; Doty et al. 2009). Such fluctuations put populations at

increased risk of extirpation and make it difficult to determine population trends. Consequently, it is necessary to develop a scientifically defensible, long-term monitoring program that can detect trends in population size and distribution.

5. Field studies that require capturing *T. m. atristriatus* should have specific goals with measurable and scientifically defensible outcomes that can directly inform management and should only be conducted by individuals with expert knowledge of the subspecies so as to minimize misidentification.

6. Additional surveys for *T. m. atristriatus* should occur in the Sacramento Mountains, especially on private or tribal lands where suitable habitats still exist, where possible and as practicable.

7. *T. m. atristriatus* and *T. canipes* can be easily misidentified (Figure 23), and misidentifications during prior studies are thought to have seriously hampered knowledge about the conservation status of *T. m. atristriatus* (Frey and Boykin 2007). Consequently, surveys for *T. m. atristriatus* should only be conducted by taxon experts that can confidently identify both species; if identifications are not incontrovertible, there is no legitimate reason to conduct surveys or other studies. As part of the verification process, it is imperative that any putative records of *T. m. atristriatus* be properly documented and archived (i.e., in an accredited museum) based on physical evidence, including tissue samples, properly taken external measurements (this requires training and practice to avoid errors), and series of high quality photographs that provide detailed views of diagnostic body parts (dorsal stripes on rump and sides; back of ears; side of head, neck, and shoulder; underside of tail; belly; dorsal surface of hindfoot). To facilitate this data collection, we recommend that a taxon expert develop a "morphological characteristics checklist report form" that could be used in the field to facilitate data collection (e.g., collection of external measurements and photographs of pelage) and that this report be archived with the associated physical evidence (e.g., voucher specimen, tissue samples, photographs). This would allow validation of species identification by other taxon experts in the future. A voucher specimen should be collected where possible and as practicable for any significant, new location or rediscovery of the Sacramento Mountains population (providing collection of an individual is not likely to compromise a relict population).

8. Livestock grazing should not be allowed within the Thurber's fescue meadow systems in the White Mountains. The potential impact of elk (*Cervus elaphus*) on this vegetation type with respect to *T. m. atristriatus* should be investigated. In addition, the impact of feral horse grazing on this system should be evaluated; increasing populations of feral horses on tribal lands and adjacent Lincoln National Forest lands is of concern.

9. As originally recommended by Sullivan and Nagorsen (1998) and reiterated by Frey and Boykin (2007), a coordinated, multi-agency management plan should be developed for *T. m. atristriatus* and involve the Mescalero Apache Tribe, Lincoln National Forest, New Mexico Department of Game and Fish, and US Fish and Wildlife Service.

Figure 23. Specimen of a Peñasco least chipmunk (*Tamias minimus atristriatus*; top) and gray footed chipmunk (*T. canipes*; bottom) captured during surveys on Lookout Mountain. Given the close morphological similarity of the two species, expertise is required for identification and preserved, physical evidence (e.g., DNA, voucher specimen, properly taken photographs) is necessary to verify identifications and properly archive data.

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