Alpine Mesocarnivore Study 2021-2022 Progress Report
California Department of Fish and Wildlife
Inland Deserts Region 6
Bishop Field Office

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A Sierra Nevada red fox detected by remote camera in the Mono Creek study area, Sierra Nevada, California in September 2022.

I. Executive Summary

Since 2016, the Bishop Field Office of the California Department of Fish and Wildlife (CDFW) has conducted annual surveys for mesocarnivores in upper elevations of the Sierra Nevada south of Yosemite National Park. The goal of these surveys is to improve our understanding of mesocarnivore distribution and occupancy in alpine environments where these animals have rarely been studied, and in a region of California where the population status of many species is unknown. As managers begin to discuss the potential risks and benefits of reintroducing SNRF and wolverines into their historical habitat in the Sierra Nevada, information about the contemporary distribution of these species, as well as the distribution of other carnivore species, will be critical to informing conservation planning.

Each winter, we systematically deploy remote cameras at elevations above 3,050 m within a focal region such as a drainage basin, divide, or subrange. Surveys are designed to detect multiple mesocarnivore species; of particular interest are detections of rare, threatened, or endangered species like Sierra Nevada red foxes (*Vulpes vulpes necator*; SNRF) and wolverines (*Gulo gulo*). When cameras detect species of interest, we follow up with ground surveys to collect scats for genetic identification. We also maintain monitoring cameras in areas with prior detections of target species and deploy cameras opportunistically in locations where habitat is suitable and year-round access is logistically feasible. Over a study period of approximately 10 years (2016–2025), we will estimate the distribution and occupancy of numerous mesocarnivore species throughout the study area.

During the 2021 survey season we surveyed the Goddard Divide study area, a region of Kings Canyon National Park and the Inyo and Sierra National Forests west of the town of Big Pine, California. We detected SNRF at one site at 3,321 m in November 2020. Other notable detections because of their occurrence at unusually high elevations were a gray fox (*Urocyon cinereoargenteus*) at 3,647 m in October 2020, a ringtail (*Bassariscus astutus*) at 3,255 m in October 2020, and a fisher (*Pekania pennanti*) at 3,376 m in April 2021. We did not detect wolverines.

During the 2022 survey season we surveyed the Cirque Crest study area, a region of Kings Canyon National Park and the Inyo National Forest between Bishop Pass and Taboose Pass. We detected SNRF on five occasions at three sites. These detections represent the first confirmed SNRF in Kings Canyon National Park since the 1930s. There were no other notable carnivore detections during this survey. We did not detect wolverines.

In addition to systematic camera surveys, we maintained opportunistic cameras during 2021–2022 and continued to detect SNRF relatively frequently in the Mono Creek and Mammoth Lakes study areas, where they have been detected consistently since 2018 and 2019, respectively. We conducted systematic scat surveys in these study areas, and also collected scats opportunistically throughout the Sierra Nevada, including in the Goddard Divide and Cirque Crest study areas. In the Mono Creek study area we detected two SNRF by scat: a male and a female that we have detected consistently in that area since 2018. In the Mammoth Lakes study area we detected scat from two male SNRF that appear to be brothers. We did not find SNRF scat in the Goddard Divide or Cirque Crest study areas.

Our camera survey methods continued to be effective in detecting mesocarnivore species such as SNRF and Pacific martens that occur at relatively low densities in alpine and subalpine zones of the Sierra Nevada. Our results confirmed the presence of SNRF in multiple locations of their historical range south of where the subspecies was thought to persist prior to this study, including in Kings Canyon National Park. In upcoming seasons, we plan to continue to monitor locations where we have detected SNRF and expand our camera surveys to adjacent areas of the Sierra Nevada identified as suitable habitat for SNRF and wolverines.

This report details our activities during January 2021–December 2022, as well as results from fall 2020 that were not included in previous reports.

II. Introduction

The distribution, abundance, and even presence of many carnivore species in the alpine zones of the Sierra Nevada are poorly understood. Prior to our study, the most recent extensive alpine survey effort targeting multiple carnivore species took place during 1996–2002 (Zielinski et al. 2005). This survey was intended to update carnivore distribution information as compared to the historical records compiled by Schempf and White (1977) and Grinnell et al. (1937). Zielinski et al. (2005) detected 13 carnivore taxa and did not detect SNRF or wolverines. Their study area consisted primarily of forested habitats below 3,200 m in the southern Sierra Nevada and below 2,700 m in the central Sierra Nevada. In contrast, our study is focused on detecting carnivore presence in the highest-elevation, most barren regions of the range where no systematic carnivore surveys have occurred at this scale and intensity. Documenting the assemblage of species that use these alpine habitats can help land and wildlife managers understand predator-prey dynamics, conserve sensitive species, and anticipate the impacts of climate change, wildfires, and human land use.

As part of our long-term study of mesocarnivores in the alpine Sierra Nevada south of Yosemite National Park, each year we choose a focal area to survey intensively. In 2021 and 2022, we selected the Goddard Divide and Cirque Crest areas, respectively. These are regions of alpine habitat that lie to the south of the Mono Creek study area in Kings Canyon National Park (Figure 1). Our primary study objective during 2021–2022 was to document mesocarnivore presence in these areas.

SNRF are of particular interest due to the endangered status of the Sierra Nevada Distinct Population Segment (DPS; USFWS 2015). Our surveys and other contemporary study efforts have detected SNRF along a 250-km stretch of the Sierra Crest encompassing much of the north-south extent of the species' historical range in the Sierra (Sierra Nevada Conservation Advisory Team 2022). Despite this extensive distribution, residence (i.e., detection of the same individuals in multiple years) and reproduction have been confirmed only in two areas separated by 120 km: the Sonora Pass and Mono Creek study areas, the latter of which was discovered during our study (Quinn et al. 2019, Hatfield et al. 2023). We have documented a resident, reproducing population of SNRF in Mono Creek since 2018, as well as numerous SNRF detections both north and south of Mono Creek. In the Mammoth Lakes study area, we have documented SNRF presence consistently since 2019, but we have not obtained repeat detections of individuals or evidence of reproduction. In the Mono Creek and Mammoth Lakes study areas, our objectives during 2021–2022 were to estimate the number of SNRF individuals present and contribute to the wider picture of genetic structure, genetic diversity, relatedness, immigration, and reproduction in the Sierra Nevada DPS by continuing to monitor their presence via cameras and obtaining genetic samples via scat.

III. Methods

We detected mesocarnivores using a combination of noninvasive methods: 1) systematic camera surveys aimed at documenting mesocarnivore presence within predefined geographic areas; 2) opportunistic cameras deployed in areas of suitable habitat with convenient year-round access or in locations where target species had been reported or detected previously; and 3) scat collection (both systematic and opportunistic) to obtain DNA from target species and identify individuals.

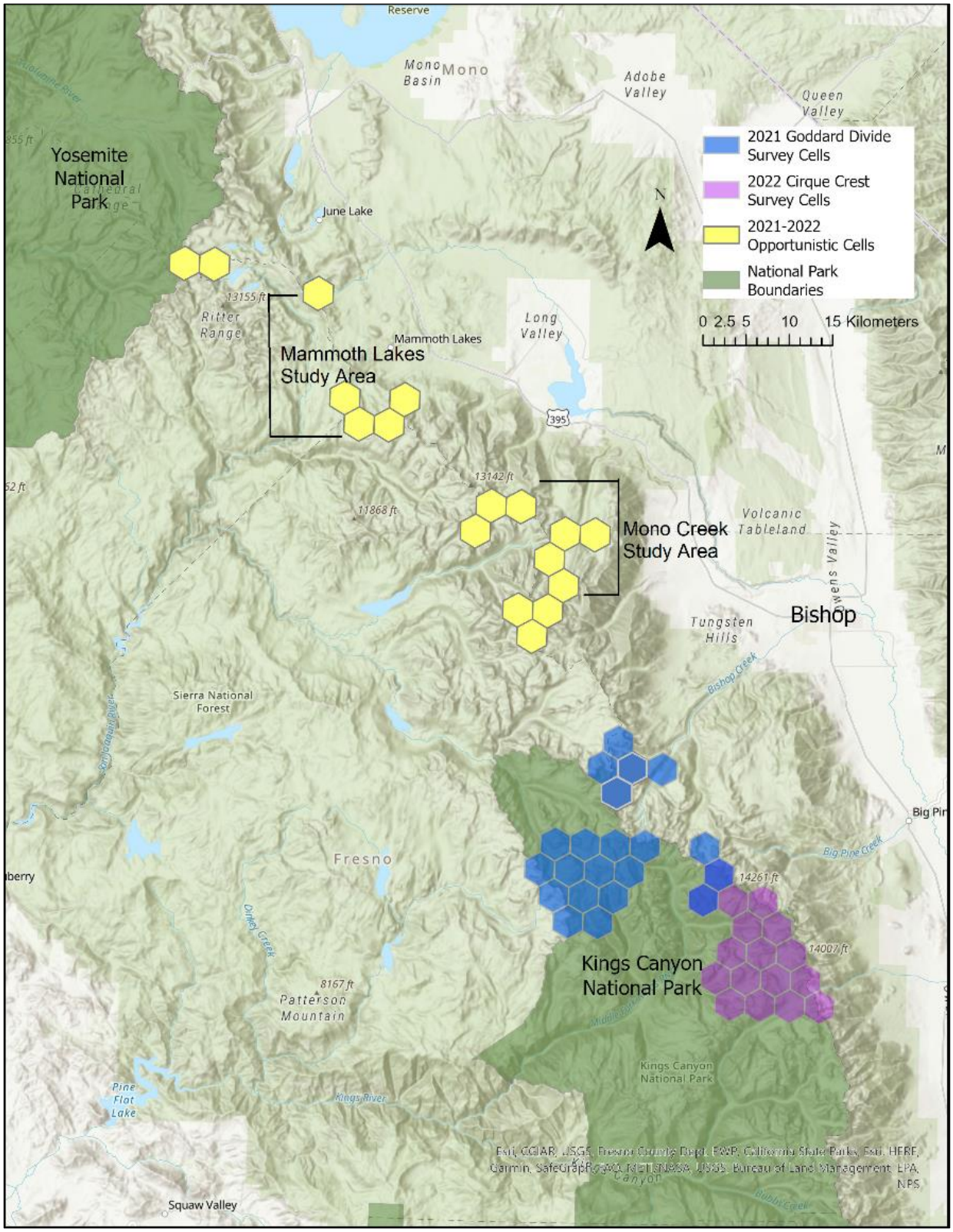

Figure 1. Map of 2021-2022 alpine mesocarnivore study areas in the Sierra Nevada, California, including systematic survey cells and opportunistic cells.

Systematic Camera Surveys

Study Areas

We selected the Goddard Divide and Cirque Crest as the focal areas for our systematic camera surveys in 2021 and 2022 based on high habitat suitability for SNRF (Cleve et al. 2011, Green et al. 2023) and proximity to areas where SNRF had been detected recently. The Goddard Divide study area encompassed portions of the Glacier Divide, Evolution Group, Black Divide, Goddard Divide, LeConte Divide, White Divide, and Sierra Crest between Piute Pass and Bishop Pass (Figure 2).

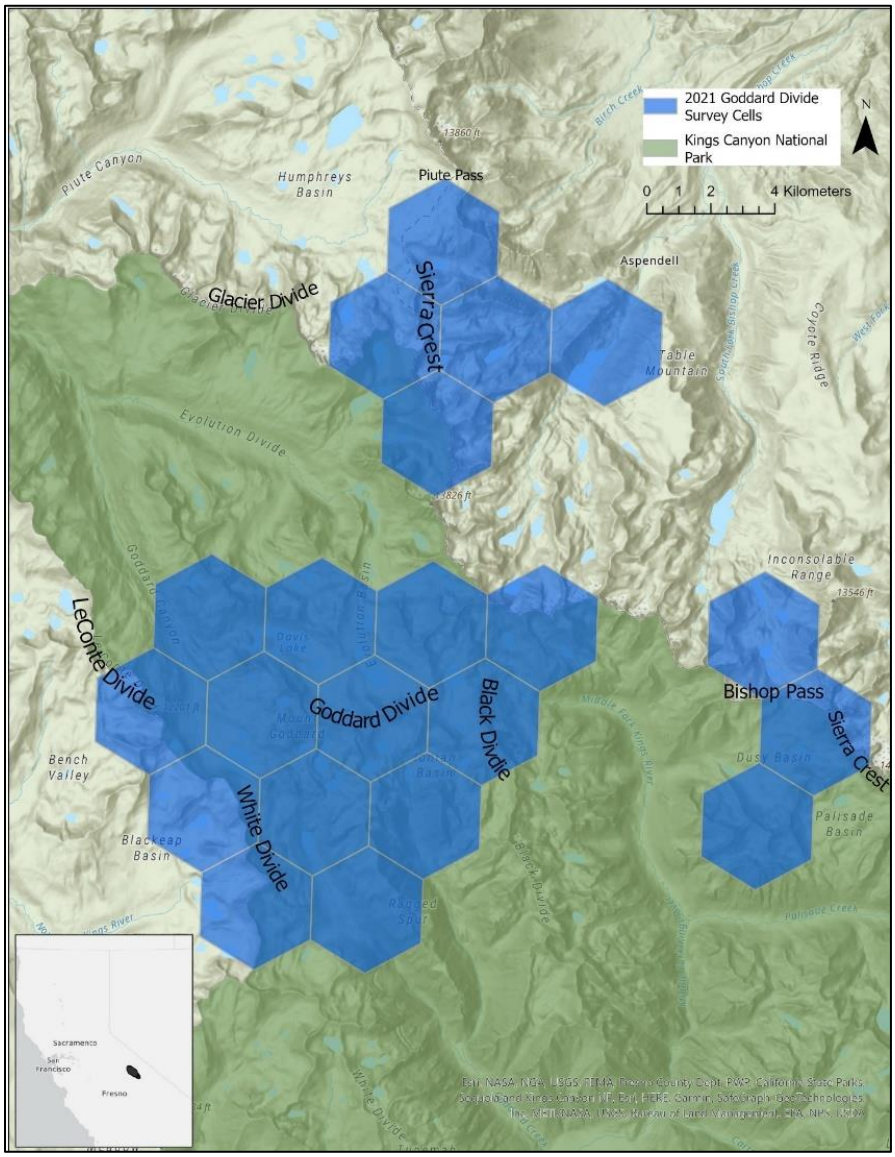

Figure 2. Survey cells comprising the 2021 Goddard Divide mesocarnivore study area in the Sierra Nevada, California.

The Cirque Crest study area began at the southern border of the Goddard Divide study area and extended along the Sierra Crest between Bishop Pass and Taboose Pass and west to the topographic feature known as the Cirque Crest, a chain of peaks bordering the South Fork of the Kings River (Figure 3).

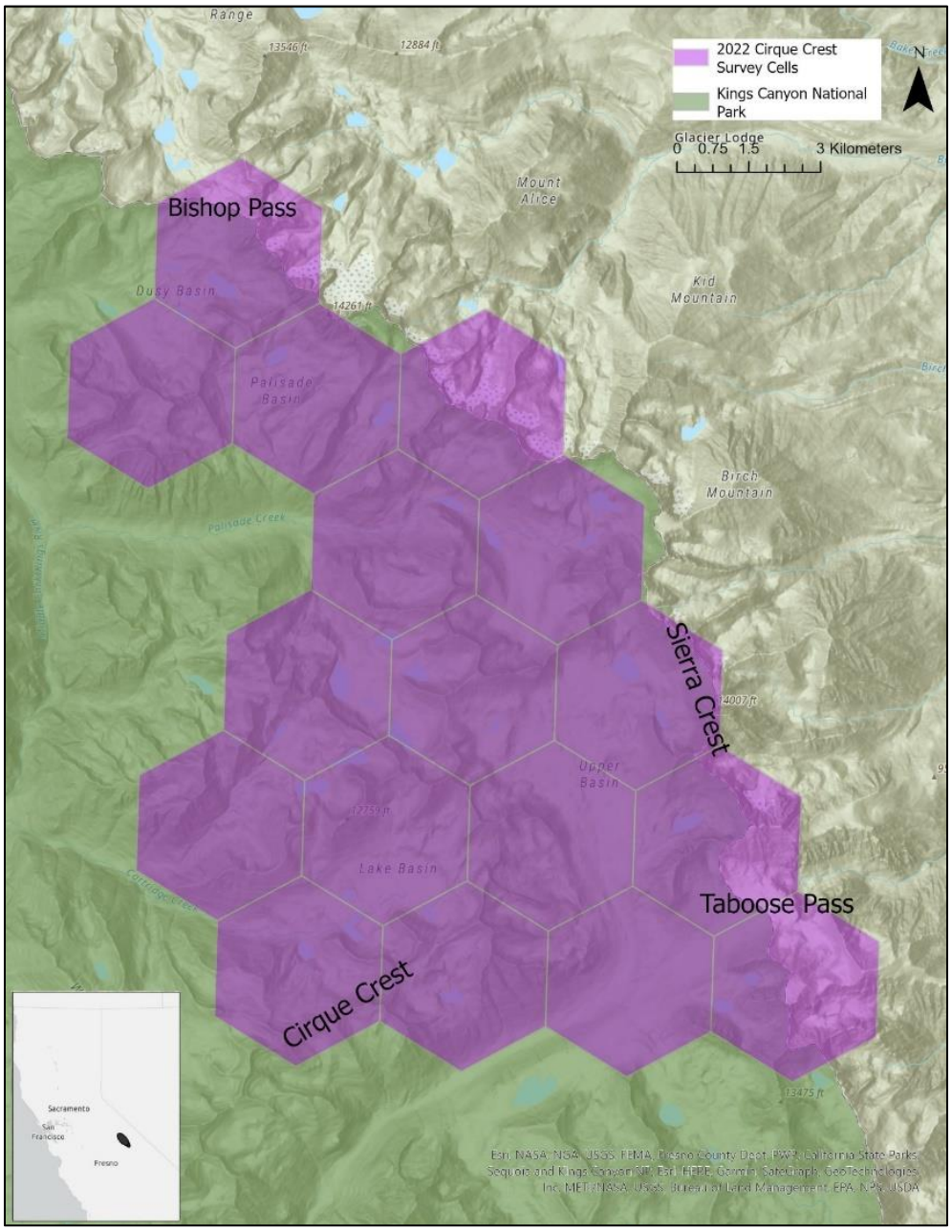

Figure 3. Survey cells comprising the 2022 Cirque Crest mesocarnivore study area in the Sierra Nevada, California.

Both study areas comprised barren alpine ridges and peaks, lake basins, meadows, and subalpine forests dominated by whitebark pine. This region of the Sierra Nevada receives most

of its annual precipitation in winter (November–May), but the amount of precipitation is highly variable between years. Both survey seasons were relatively dry, with 43% of April 1 average snow water equivalent in 2021 and 42% of April 1 average in 2022 (source: https://cdec.water.ca.gov).

Field Methods

We determined placement for camera sites using a grid of 10.4 km^2 hexagons laid over each study area, adapting a CDFW protocol used successfully to detect SNRF and other mesocarnivores in the Sonora Pass area (Stermer 2015). We deployed two cameras per hexagon to increase the total area sampled. We used Lidar snow depth data at a 3-m pixel resolution (Airborne Snow Observatory, Mammoth Lakes, CA) to refine fine-scale site selection for cameras by identifying areas with low snow accumulation, such as barren alpine passes exposed to prevailing winds. Such passes may function as travel corridors for wildlife and are less likely to become buried in snow. In our experience, placing cameras on exposed passes can increase the number of days when cameras are operational. Approximately half of the winter camera placements in the Goddard Divide and Cirque Crest study areas were located on passes. The remaining cameras were located on windswept ridges, knolls, or other features that typically accumulated minimal snow, as well as along trails likely to be used by wildlife.

We deployed Reconyx motion detection cameras (Reconyx, Holmen, Wisconsin, USA) with commercial scent lure (Gusto, Minnesota Trapline Products, Pennock, Minnesota, USA) placed 3–5 m away from each camera to attract carnivores. We attached cameras with bungee cords or cam straps to large boulders or trees (Figure 4). We programmed camera triggers at a high sensitivity setting and set cameras to take 10 photos per trigger. Most stations were active for a minimum of 120 days, with a target revisit rate of at least once per camera during the survey season. During revisits, we added fresh lure, collected and replaced the cameras' memory cards and batteries, and adjusted the cameras as needed.

When we moved cameras from their original locations during a survey, we treated the new locations as new sample points, adding them to the total number of sample points for that survey. In 2021, we deployed 39 camera stations across 21 grid cells in the Goddard Divide study area at elevations from 3,062 m to 3,749 m. This includes 35 initial camera placements and 4 cameras that we moved in April 2021 to more windswept locations. In 2022, we deployed 44 cameras across 17 grid cells at elevations between 3,252 m and 3,754 m. This includes 36 initial camera placements and 8 cameras that we moved in June 2022 from their winter locations to new locations with higher probabilities of detection for carnivores in summer (e.g., meadows and lakeshores).

Figure 4. A camera sampling site in the Goddard Divide mesocarnivore study area, Sierra Nevada, California.

Opportunistic Cameras

We maintained opportunistic cameras in two primary study areas: Mono Creek and Mammoth Lakes. Both are areas where we have detected SNRF consistently for multiple years and where we know or suspect that SNRF reside. In addition to these two primary study areas, we deployed opportunistic cameras in several other locations within our broader survey region (Figure 5), including the Ritter Range (surveyed systematically in 2019), the Silver Divide (surveyed systematically in 2020), Bear Lakes Basin (not surveyed systematically), the Goddard Divide (surveyed systematically in 2021), and the Rock Creek drainage (surveyed systematically in 2016).

Study Areas

The Mono Creek study area was adjacent to Rock Creek and McGee Creek and east of Lake Thomas Edison (Figure 5). Mono Creek bisected this study area with the Silver Divide to the north and the Mono Divide to the south. Each divide comprised a series of granite peaks and ridges enclosing hanging basins with lake and meadow complexes. We surveyed this study area systematically in 2018 and have maintained opportunistic cameras there since then.

The Mammoth Lakes study area encompassed the Mammoth Lakes Basin and the San Joaquin Ridge (Figure 5). The Mammoth Lakes Basin is a drainage south of Mammoth Lakes, California and north of the Mono Creek study area. A volcanic ridge called the Mammoth Crest encloses a north-facing lake basin characterized by montane mixed-conifer forest. The San Joaquin Ridge is a volcanic ridge of the Sierra Crest between the towns of Mammoth Lakes and June Lake. We surveyed the Mammoth Lakes Basin systematically in 2016 and have maintained opportunistic cameras there since then. The San Joaquin Ridge has never been part of a systematic survey, but we have maintained opportunistic cameras there since 2020.

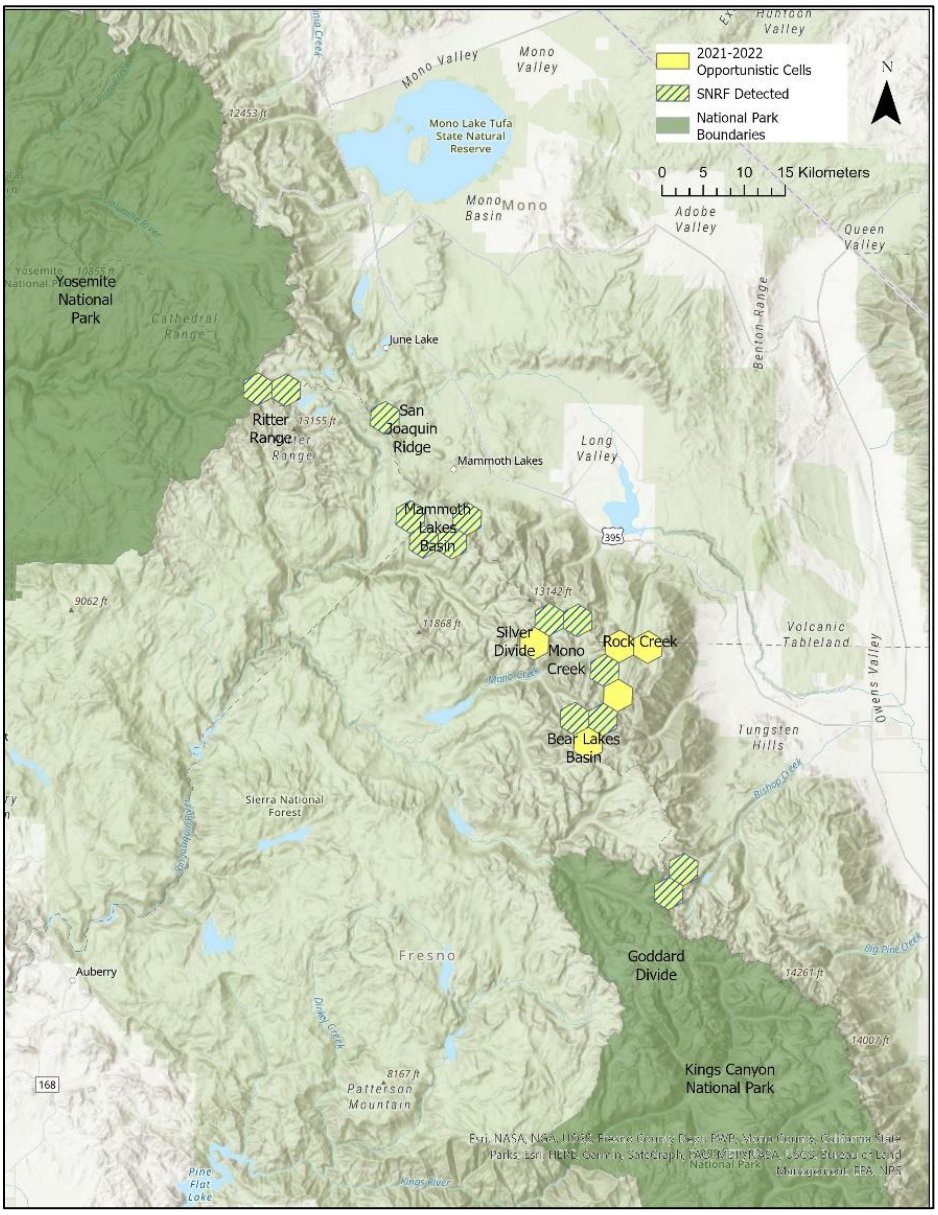

Figure 5. Opportunistic camera locations in 2021 and 2022 and cells where opportunistic cameras have detected SNRF in the Sierra Nevada, California.

Field Methods

We followed a similar protocol to deploy opportunistic cameras as that described above for systematic survey cameras. However, rather than being deployed systematically across a focal geographic area, opportunistic cameras were deployed in areas where we had previously detected SNRF, or in areas that were likely to remain windswept and had reasonable year-round access. Opportunistic cameras were often left in place for longer than survey cameras—sometimes for multiple years—and were revisited and rebaited when possible based on conditions and staff availability. Due to these differing methods, we do not include results from opportunistic cameras in our summary statistics. Instead, we present only notable species detections from opportunistic cameras.

In the Mono Creek study area, we maintained opportunistic cameras in six locations where we have detected SNRF since 2018: Steelhead Pass, Crocker Col, Mt. Starr Ridge, Trail Pass, Mono Pass, and Gabbot Pass. These cameras were placed in barren alpine habitat at elevations from 3,467 m to 3,738 m.

In the Mammoth Lakes study area, we maintained opportunistic cameras in seven locations along the Mammoth Crest in subalpine forest and barren alpine habitat at elevations from 3,044 m to 3,409 m, and on two barren passes along the San Joaquin Ridge at elevations of 3,019 m and 3,186 m. We selected these locations because they appeared to be potential wildlife travel corridors that were easily accessible by field staff during day trips and they were unlikely to become buried in snow.

We also maintained opportunistic cameras in two locations in the Ritter Range study area where we detected SNRF in 2019, in two locations in the Silver Divide study area, three locations in the Bear Lakes Basin, and 10 locations in Rock Creek where we felt confident there was a high probability of detection for carnivores, and in two locations in the Goddard Divide study area where we detected SNRF in 2020 and 2021.

Photo Identification

We classified photos containing images of wild animals by species and number of individuals per detection. A camera detection can be susceptible to two types of error: the same individual could be detected multiple times and counted as multiple individuals, or multiple individuals of the same species could be consolidated into a single detection. We defined a detection as a single species detected at a single camera within a 30-minute window. With this definition, we

attempted to minimize both types of error. For each wildlife detection event, we classified each individual to species and counted the number of individuals per species. We did not attempt to identify mice or chipmunks to species, though several species were present in our study area. When photos clearly contained an animal but we were unable to identify the species, we attempted to classify these to genus, family, or order. Animal detections that we were unable to identify to order constitute a very small proportion of our results, and we do not report them here.

Scat Surveys

We conducted scat surveys in cells where SNRF were detected by cameras, as well as adjacent cells with connecting trails or topographic features. During scat surveys, field staff traversed terrain features where scat was most detectable, such as trails, ridges, and passes. We collected all apparent canid scats following a noninvasive DNA sampling protocol developed by the Mammalian Ecology and Conservation Unit at the University of California, Davis (UC Davis; 2014). We also collected scat opportunistically during camera set-up and revisit trips. After returning from the field, we placed each scat in a sample tube with ethanol and mailed the samples to the Mammalian Ecology and Conservation Unit for DNA analysis. This analysis included identification of species, and, for SNRF samples, identification of individual, haplotype, sex, and pelage color. Samples from 2022 were first genotyped to species by the CDFW Wildlife Genetics Research Unit; further individual analyses of SNRF scats were performed by the Mammalian Ecology and Conservation Unit.

IV. Results

Systematic Camera Surveys

<u>Goddard Divide</u>

During our 2021 Goddard Divide camera survey, 39 survey cameras were operational for 8,538 nights out of 8,767 nights deployed (97%; Figure 6). These tallies include 35 survey cameras deployed in fall 2020 and an additional four cameras moved to new locations in spring 2021 to reduce the risk of being buried in snow. We captured 34 bird detections and 1,071 mammal detections representing at least 9 bird species[1] and 22 mammal species (Table 1). We detected 11 carnivore species, including the SNRF. We did not detect wolverines.

[1] Buff-bellied pipit, Clark's nutcracker, common raven, gray-crowned rosy finch, mountain bluebird, prairie falcon, red-tailed hawk, white-tailed ptarmigan, and an unidentified sparrow, as well as five detections of unidentified birds.

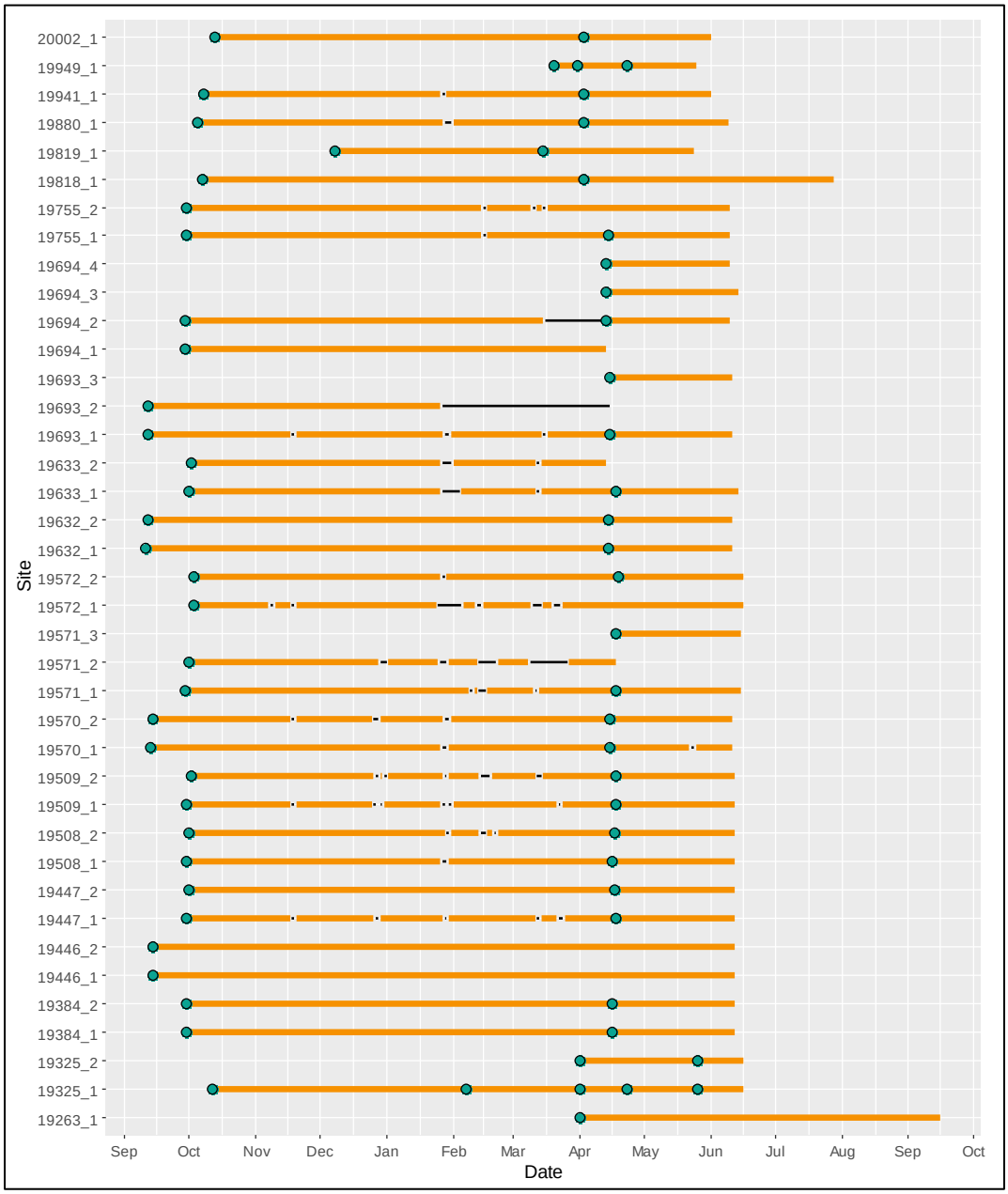

Figure 6. Operational and nonoperational periods for remote cameras in the Goddard Divide study area, Sierra Nevada, California during the 2021 survey season. Orange lines are time periods when cameras were operational, black lines are when cameras were nonoperational, and blue dots are when lure was applied.

Cirque Crest

During our 2022 Cirque Crest camera survey, 44 survey cameras were operational for 9,512 nights out of 10,208 nights deployed (93%; Figure 7). These tallies include 36 cameras deployed in fall 2021 and 8 cameras moved to new locations in summer 2022 to improve probabilities of detection for carnivores in summer. We captured 203 bird detections and 2,349 mammal

detections representing 15 bird species[2] and at least 20 mammal species (Table 2). We detected 9 carnivore species, including the SNRF. We did not detect wolverines.

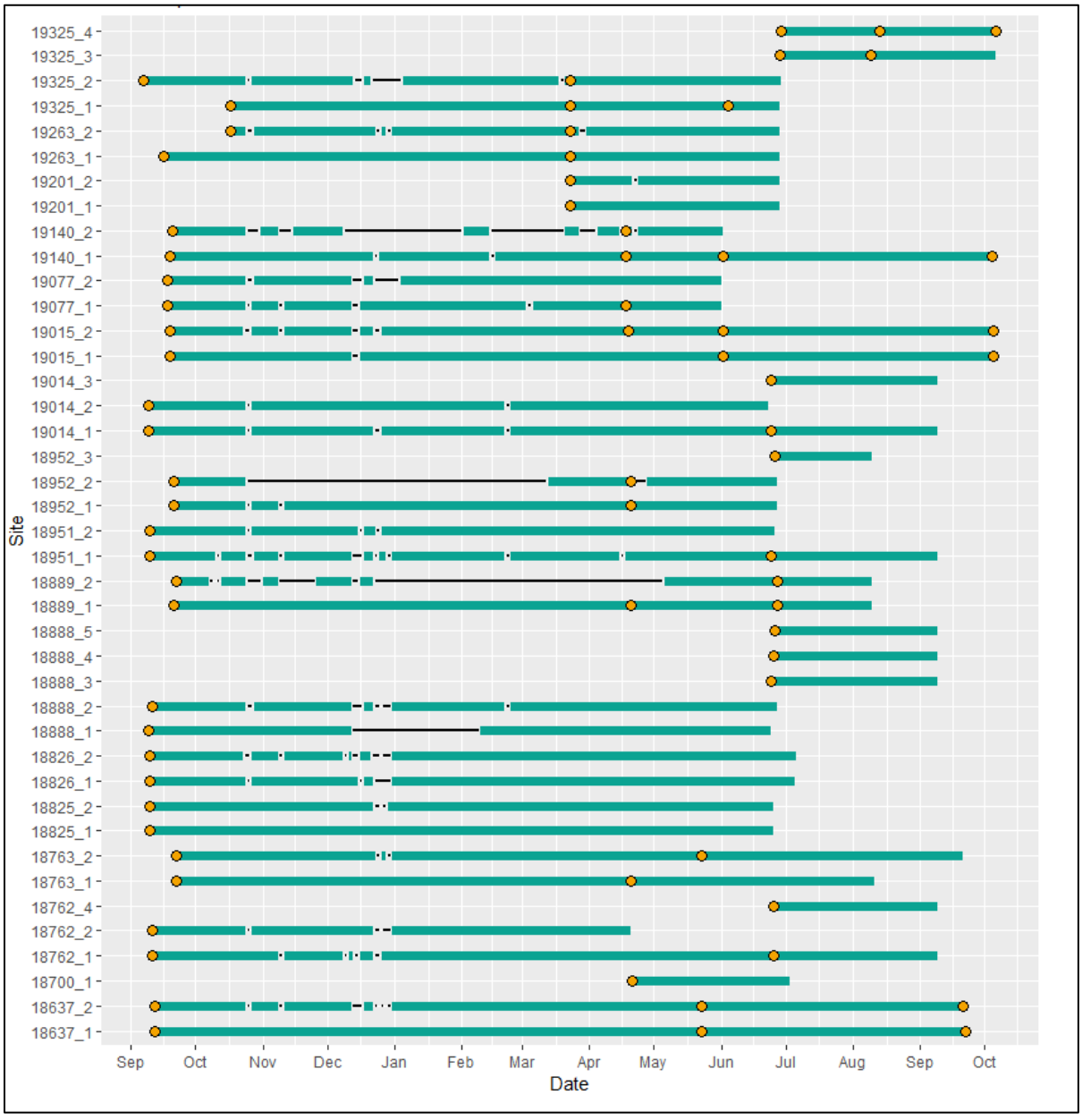

Figure 7. Operational and nonoperational periods for remote cameras in the Cirque Crest study area, Sierra Nevada, California during the 2022 survey season. Turquoise lines are time periods when cameras were operational, black lines are when cameras were nonoperational, and orange dots are when lure was applied.

[2] American robin, buff-bellied pipit, chukar, Clark's nutcracker, common raven, dark-eyed junco, gray-crowned rosy finch, hermit thrush, mountain bluebird, mountain chickadee, northern flicker, pinyon jay, rock wren, white-crowned sparrow, and white-tailed ptarmigan, as well as 26 detections of unidentified birds.

Table 1. Mammal detections during 2021 in the Goddard Divide mesocarnivore study area, Sierra Nevada, California.

Species	Order	Detections	Sites (% of Total)
Coyote	Carnivora	254	26 (67%)
Pacific marten	Carnivora	118	29 (74%)
Short-tailed weasel	Carnivora	13	9 (23%)
Bobcat	Carnivora	11	5 (13%)
Long-tailed weasel	Carnivora	2	1 (3%)
American black bear	Carnivora	2	2 (5%)
Ringtail	Carnivora	1	1 (3%)
Red fox	Carnivora	1	1 (3%)
Mountain lion	Carnivora	1	1 (3%)
Gray fox	Carnivora	1	1 (3%)
Fisher	Carnivora	1	1 (3%)
Yellow-bellied marmot	Rodentia	129	20 (51%)
Bushy-tailed woodrat	Rodentia	117	14 (36%)
Golden-mantled ground squirrel	Rodentia	95	11 (28%)
Chipmunk *sp*.	Rodentia	61	16 (41%)
Belding's ground squirrel	Rodentia	16	4 (10%)
Douglas squirrel	Rodentia	7	6 (15%)
Squirrel *sp*.	Rodentia	4	3 (8%)
Mouse *sp*.	Rodentia	2	1 (3%)
Rodent *sp*.	Rodentia	2	2 (5%)
White-tailed jackrabbit	Lagomorpha	138	16 (41%)
American pika	Lagomorpha	87	17 (44%)
Mountain cottontail	Lagomorpha	1	1 (3%)
Mule deer	Artiodactyla	4	2 (5%)

Table 2. Mammal detections during 2022 in the Cirque Crest mesocarnivore study area, Sierra Nevada, California.

Species	Order	Detections	Sites (% of Total)
Coyote	Carnivora	344	33 (75%)
Pacific marten	Carnivora	87	16 (36%)
Bobcat	Carnivora	35	14 (32%)
Short-tailed weasel	Carnivora	18	7 (16%)
American black bear	Carnivora	7	4 (9%)
Long-tailed weasel	Carnivora	6	4 (9%)
Red fox	Carnivora	5	3 (7%)
Weasel *sp*.	Carnivora	2	2 (5%)
Western spotted skunk	Carnivora	1	1 (2%)
Mountain lion	Carnivora	1	1 (2%)
Golden-mantled ground squirrel	Rodentia	371	20 (45%)
Yellow-bellied marmot	Rodentia	342	29 (66%)
Bushy-tailed woodrat	Rodentia	260	24 (55%)
Chipmunk *sp*.	Rodentia	249	31 (70%)
Rodent *sp*.	Rodentia	35	7 (16%)
Belding's ground squirrel	Rodentia	34	4 (9%)
Douglas squirrel	Rodentia	17	8 (18%)
Squirrel *sp*.	Rodentia	14	8 (18%)
Mouse *sp*.	Rodentia	4	4 (9%)
Woodrat *sp*.	Rodentia	1	1 (2%)
White-tailed jackrabbit	Lagomorpha	180	22 (50%)
American pika	Lagomorpha	144	22 (50%)
Mule deer	Artiodactyla	147	10 (23%)
Sierra Nevada bighorn sheep	Artiodactyla	45	5 (11%)

Opportunistic Cameras

We obtained repeated detections of SNRF on opportunistic cameras in the Mono Creek and Mammoth Lakes study areas during 2021 and 2022, both on cameras that had detected SNRF in the past and on new cameras placed during this study period (Figure 8). We also detected SNRF on one opportunistic camera in the Goddard Divide study area in December 2021, near where a survey camera had detected a SNRF during the Goddard Divide survey the prior year.

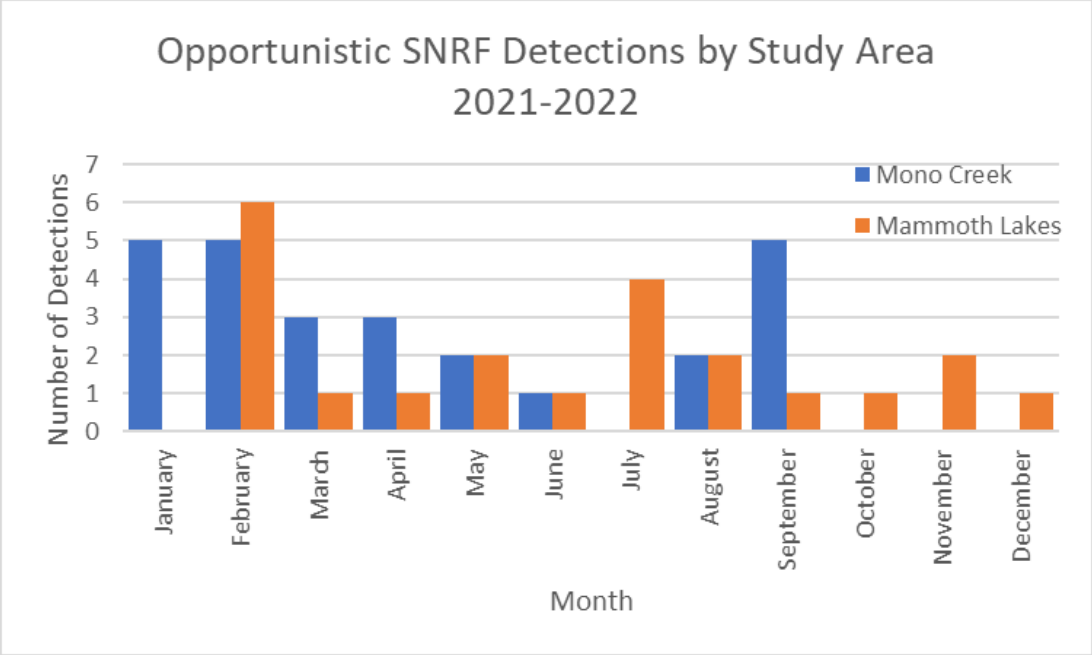

Figure 8. Number of SNRF detections by month on opportunistic cameras in the Mono Creek and Mammoth Lakes study areas in 2021 and 2022.

Scat Surveys

In 2021, we collected 305 scat samples (135 from the Mono Creek study area, 35 from the Mammoth Lakes study area, 126 from Sequoia and Kings Canyon National Parks [including the Goddard Divide and Cirque Crest study areas], and nine from Yosemite National Park; Figure 9; Table 4). The majority of scat samples from all study areas were coyote. We found SNRF scats (n = 21) only in the Mono Creek study area. All SNRF scats were from two individuals, male 2017-6 (n = 9) and female 2018-1 (n = 12), that we have detected annually in Mono Creek since 2018.

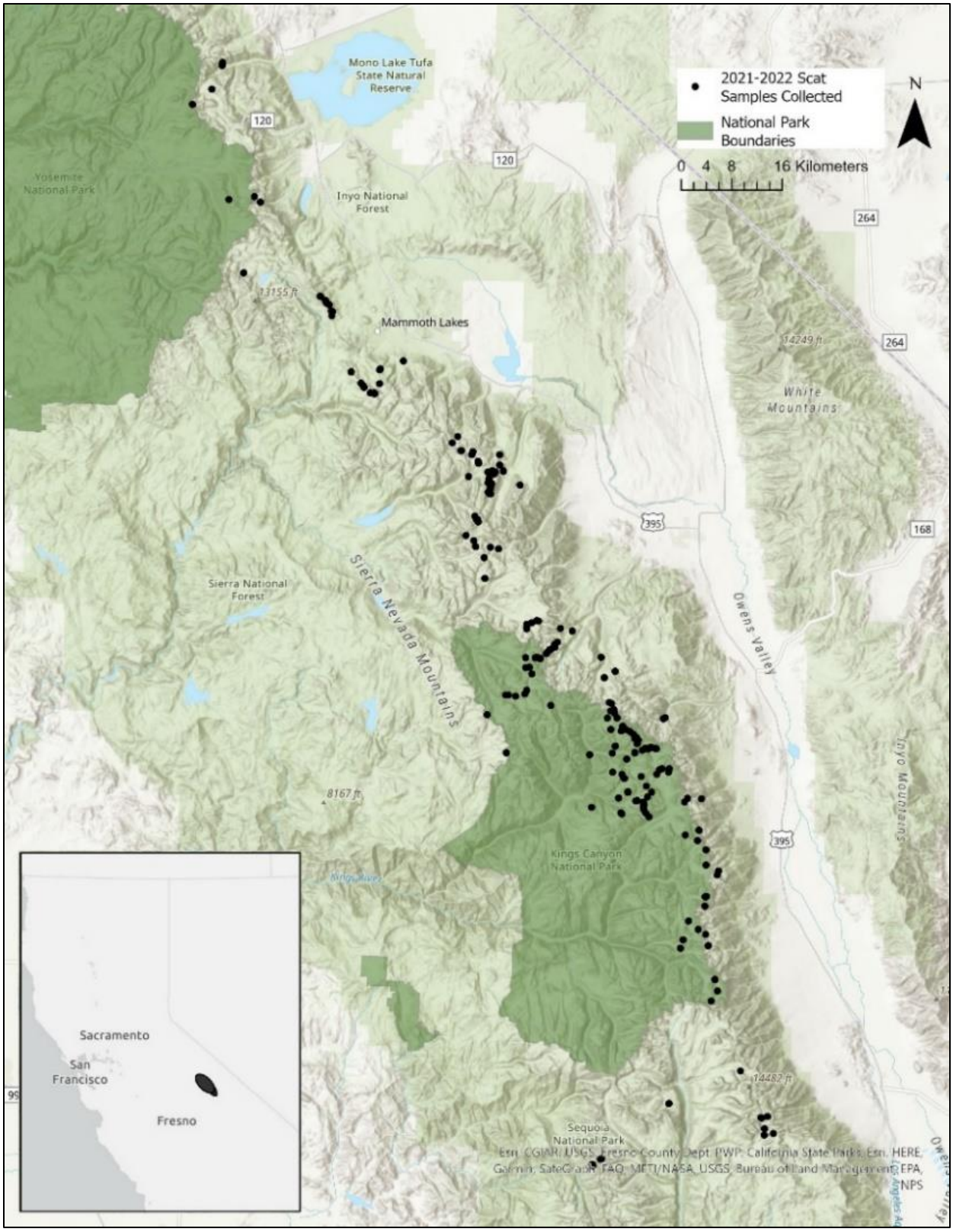

Figure 9. Locations of scat samples collected in the Sierra Nevada, California in 2021 and 2022.

Table 4. Scat samples from the Sierra Nevada, California collected during 2021 and genotyped to species.

Species	Mono Creek	Mammoth Lakes	Sequoia and Kings Canyon National Parks	Yosemite National Park	**Total**
Coyote	44	28	83	2	**157**
Red fox	21	0	0	0	**21**
Pacific marten	11	0	4	1	**16**
Bobcat	1	4	6	0	**11**
Domestic dog	5	0	0	0	**5**
Gray fox	3	0	1	4	**8**
Black bear	0	1	0	0	**1**
Unidentified prey species	1	0	0	0	**1**
Unable to determine	49	2	32	2	**85**
Total	**135**	**35**	**126**	**9**	**305**

In 2022, we collected 128 scat samples (58 from the Mono Creek study area, 15 from the Mammoth Lakes study area, 54 from Sequoia and Kings Canyon National Parks, and 1 from Yosemite National Park; Figure 9; Table 5). Again, coyote scats made up the majority of the samples from all study areas. We collected 11 SNRF scats from the Mono Creek study area and 4 SNRF scats from the Mammoth Lakes study area. Three of the SNRF scats from Mono Creek did not yield sufficiently high-quality DNA for individual identification. Of the remaining eight scats, four were from male 2017-6 and four were from female 2018-1, the individuals that appear to reside in that study area. In Mammoth Lakes, the SNRF scats came from two males, 2023-1 (n = 3) and 2023-11 (n = 1). These individuals appear to be siblings (B. Sacks, UC Davis, personal communication 2023).

Other SNRF Detections

Cameras in Yosemite National Park photographed SNRF in four new locations during 2021 and 2022, all in the southern portion of the park (M. McDonald, NPS, personal communication 2022), near where our cameras detected SNRF in the Ritter Range in 2019 (Hatfield et al. 2023). CDFW Headquarters staff detected SNRF by remote camera near Carson Pass and Monitor Pass, approximately 26 km to the north and 21 km to the northeast, respectively, of the northernmost previous detections (C. Stermer, CDFW, personal communication 2022). Members of the public submitted photographic detections of a red fox in February and May

2022 in the Washoe Valley northeast of Lake Tahoe (C. Quinn, UC Davis, personal communication 2023), as well as a video detection of a red fox in April 2023 at Sugar Bowl Ski Resort northwest of Lake Tahoe (P. Figura, CDFW, personal communication 2023). A red fox carcass was found along Highway 88 west of Carson Pass in September 2022 (C. Loffland, USFS, personal communication 2022).

Table 5. Scat samples from the Sierra Nevada, California collected during 2021 and genotyped to species.

Species	Mono Creek	Mammoth Lakes	Sequoia and Kings Canyon National Parks	Yosemite National Park	**Total**
Coyote	28	11	35	1	**75**
Red fox	11	4	0	0	**15**
Bobcat	2	0	4	0	**6**
Gray fox	0	0	3	0	**3**
Domestic dog	1	0	0	0	**1**
Black bear	1	0	0	0	**1**
Unable to determine	15	0	12	0	**27**
Total	**58**	**15**	**54**	**1**	**128**

V. Discussion

In the Goddard Divide study area, coyotes and Pacific martens were the most commonly detected carnivores and the species detected at the highest proportion of sites (254 and 118 detections at 67% and 74% of sites, respectively). Unusual detections in this study area included a SNRF at 3,634 m in November 2020, a gray fox at 3,647 m in October 2020, a ringtail at 3,255 m in October 2020, and a fisher at 3,376 m in April 2021. Gray foxes and ringtails are common species, but they are typically associated with lower elevations. Historically, gray foxes were found to be most abundant between 1,150 m and 1,525 m in the Sierra, although their occupancy at elevations over 2,000 m has increased by 25–30% in the last decade (Tucker et al. 2019). Ringtails are described as “a species of the mid-to-lower elevations” (Zielinski et al. 2005: 1395) with a range extending only to 2,680 m in California (Orloff 1988; Schempf and White 1977). Fishers in California have occasionally been found at elevations over 3,000 m (including by our surveys; see Hatfield et al. 2023), but they typically select for dense, mature conifer forests (Spencer et al. 2015). We presume that our detections of these three species represent anomalous exploratory movements rather than permanent residence in the alpine.

In the Cirque Crest study area, by far the most commonly and widely detected carnivore species was the coyote (344 detections at 75% of sites). Pacific martens were also detected frequently and across much of the study area (87 detections at 36% of sites). While there were fewer bobcat detections (35), this species was detected broadly throughout the study area, at almost as many sites as were Pacific martens (32%).

We detected SNRF at one site in the Goddard Divide study area in November 2020, and at three sites in the Cirque Crest study area on five occasions in April, May, and June 2022. These detections extended the boundary of the known SNRF distribution approximately 45 km south of the Mono Creek study area where we have documented a reproducing population (Hatfield et al. 2023). The detections in the Cirque Crest study area marked the first time the species has been confirmed in Kings Canyon National Park since the 1930s, when sightings there were verified by Grinnell et al. (1937). Because we have not yet obtained genetic samples from SNRF in these areas, we do not know whether the detections represent multiple individuals, their ancestry, or whether they have been detected previously in other areas. The presence of SNRF in these study areas after nearly a century without a confirmed detection suggests that their distribution may be expanding. An alternative explanation is that increased survey effort has led to the detection of a remnant population that had existed unnoticed in the area since the 1930s. Without genetic samples, it is challenging to discriminate between these possibilities.

We surveyed the Mammoth Lakes study area systematically in 2016 and have maintained monitoring cameras there every season since. We first detected a SNRF in the study area in 2019. We had one SNRF detection in the study area in 2020 and five detections in 2021. In 2022, we had 17 SNRF detections at six sites, including 12 detections at the same site on Sherwin Ridge. We did not find any SNRF scats in the Mammoth Lakes study area in 2021. In 2022 we found four scats from two individuals. The individuals were brothers and were sampled in the same location on Sherwin Ridge. Although we had photo detections at five other locations in the study area in 2022, we did not obtain SNRF scats anywhere else. The increase in photo and scat detections in the Mammoth Lakes study area may suggest a population increase, an immigration event, or simply the presence of a small number of highly detectable individuals. Future genetic samples of SNRF from other locations in the Mammoth Lakes study area would help to determine whether multiple family groups are present in the study area. Photo detections span more than 20 linear km, suggesting that multiple home ranges could be accommodated.

In the Mono Creek study area, we also obtained more photo detections of SNRF in 2022 (n = 19) than in 2021 (n = 8). All individually identifiable SNRF scats came from two individuals,

2017-6 (male) and 2018-1 (female), that we have detected annually in Mono Creek since 2018. We infer that these individuals are a mated pair based on the detection of scats from their offspring in 2020. The male, 2017-6, was first detected near Sonora Pass in 2017, more than 120 km to the north. The female, 2018-1, is his close relative (sibling or offspring), indicating that she also came from Sonora Pass (B. Sacks, UC Davis, personal communication 2023). Although we sampled two offspring produced by the pair in 2020 (Hatfield et al. 2023), we did not detect any offspring, or any other individuals, in this study area in 2021 or 2022. Despite the increase in photo detections in 2022, genetic evidence does not suggest a population increase in Mono Creek.

Based on the repeated and widespread detections of SNRF throughout the Sierra in recent years, it is likely that the SNRF population is genetically continuous from near Lake Tahoe in the north to Kings Canyon National Park in the south (Figure 10).

In seven years of surveys, we have consistently documented widespread presence of Pacific martens throughout our study area. Although martens are described in the literature as mature forest specialists (Zielinski et al. 2005, Moriarty et al. 2011, Martin et al. 2021), it is clear that they make extensive use of barren alpine habitat in the Sierra Nevada, including in winter. The martens detected in our study may be individuals that select for alpine habitat exclusively, or whose home ranges encompass both mature forest and alpine habitat types. Interestingly, we have captured multiple photos of martens with prey species that live at high elevations, such as American pikas (*Ochotona princeps*) and yellow-bellied marmots (*Marmota flaviventris*; Figure 11), confirming that the diet of martens in our study area includes alpine prey species.

Our camera survey methods have demonstrated the prevalence of carnivores like coyotes and Pacific martens in alpine habitat throughout the Sierra Nevada south of Yosemite National Park. We have also detected the presence in the alpine of carnivores whose range was thought to be restricted to lower elevations, indicating that species associated with very different habitats occasionally disperse through the alpine. Finally, our surveys have established SNRF occupancy throughout much of their historical range in the southern Sierra Nevada, greatly expanding the scope of future efforts to recover this endangered population.

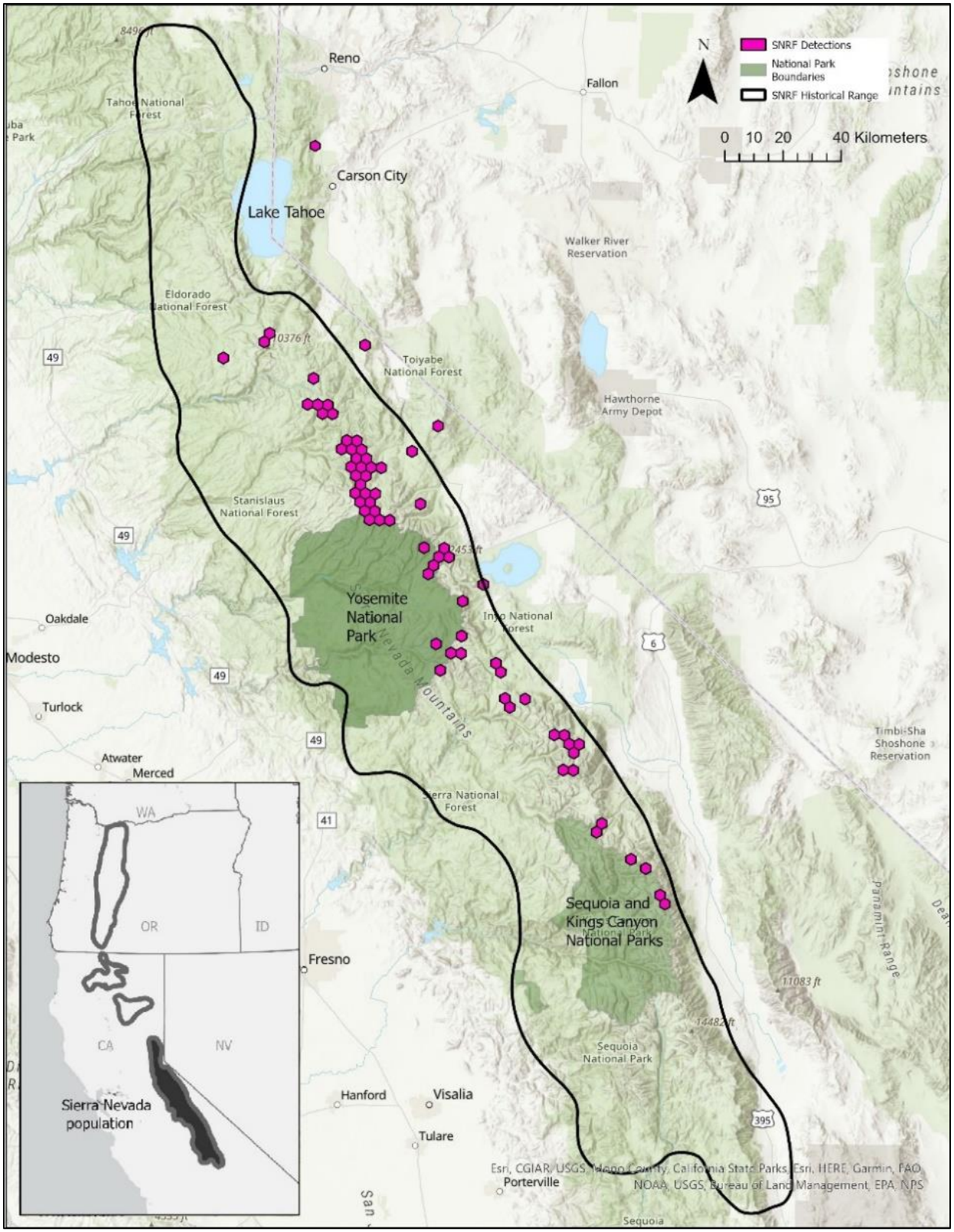

Figure 10. Cells where SNRF have been detected in the Sierra Nevada, California, during 2010–2022. Historical range is adapted from Grinnell et al. 1937 by Perrine et al. 2010.

Figure 11. Pacific marten with yellow-bellied marmot prey at 3,662 m elevation in the Goddard Divide study area, Sierra Nevada, California.

We plan to continue our systematic survey for a minimum of three more seasons (2023, 2024, and 2025). The next step in our study will be data analysis to enable more sophisticated interpretation of our survey results. To date, using our existing survey and monitoring data, we have built draft models estimating occupancy and detection rates by survey season for SNRF and sympatric coyotes. These models estimate the impacts of several covariates on species detection rates, including use of scent lure, Julian date, prey presence, and habitat covariates such as maximum snow depth, elevation, aspect, slope, topographic position index, and vegetation. We have also developed a draft mixture model estimating prey abundance of white-tailed jackrabbit, pika, marmot, golden-mantled ground squirrel, Belding's ground squirrel, woodrat *sp*., and chipmunk *sp*. to enable evaluations of predator-prey relationships in the study area. In future, we plan to refine these models and use them to estimate occupancy of additional sympatric carnivores in the study area, such as Pacific martens and bobcats. Based on our results, we will evaluate our survey methodologies and opportunities for improving detection rates of mesocarnivores in the alpine Sierra Nevada to allow for long-term monitoring and conservation of these species.

VI. Acknowledgements

Numerous CDFW personnel contributed to this project through fieldwork assistance, data processing, and advice, including Kathleen Anderson, Michael Brown, Todd Calfee, Dave German, Lacey Greene, Phil Johnston, Cody Massing, Elsbeth Otto, Liz Siemion, Tom Stephenson, Chris Stermer, and Jon Weissman. CDFW Region 4 and Headquarters staff worked with us to coordinate survey locations. Cate Quinn, Ben Sacks, and Stevi Vanderzwan of the Mammalian Ecology and Conservation Unit at UC Davis and Mike Buchalski and Alicia Kubicki of the CDFW Wildlife Genetics Research Unit performed genetic analysis of scat samples. The Inyo National Forest, Sierra National Forest, and Sequoia and Kings Canyon National Parks provided helpful support for backcountry survey logistics. This project was funded by the Pittman-Robertson Act (Federal Aid in Wildlife Assistance).

Suggested Citation

Hatfield, B. E., J. R. Lawson, and D. J. Gammons. 2024. Alpine mesocarnivore study 2021-2022 progress report. California Department of Fish and Wildlife, Inland Deserts Region 6, Bishop Field Office.

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