2019-2020 Alpine Mesocarnivore Study Progress Report
California Department of Fish and Wildlife
Inland Deserts Region 6
Bishop Field Office

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A black-pelage Sierra Nevada red fox juvenile detected by camera in Mono Creek, Sierra Nevada, California in September 2020.

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 impetus for 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. Each winter, we deploy remote cameras at elevations above 2,700 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 luscus*). 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 2019 survey season we surveyed the Ritter Range, a subrange of the Sierra Nevada south of Yosemite National Park and west of the town of Mammoth Lakes. We detected SNRF at two sites in the Ritter Range in May and June 2019. Other notable detections include a fisher (*Pekania pennanti*) at 3,294 m and a kit fox (*Vulpes macrotis*) at 3,303 m. We did not detect wolverines.

During the 2020 survey season we surveyed the Silver Divide, a drainage divide southeast of Mammoth Lakes that separates the Fish Creek and Mono Creek watersheds. We did not detect SNRF or wolverines in this study area. The only unusual detection was a gray fox (*Urocyon cinereoargenteus*) at 3,393 m.

In addition to systematic camera surveys, we maintained opportunistic cameras during 2019—2020 in the Mono Creek study area where we detected SNRF in 2018. We also deployed opportunistic cameras in the Mammoth Lakes study area. Opportunistic cameras in Mono Creek continued to detect SNRF in 2019 and 2020, and we obtained new detections from two sites in the Mammoth Lakes study area. We conducted systematic scat surveys in areas of Mono Creek, and also collected scats opportunistically throughout the Sierra Nevada. SNRF scats collected from Mono Creek represented four individuals—a male and a female that were sampled previously in 2018, and a male and a female that are likely the offspring of those two adults based on parentage analysis. A female SNRF sampled in Mono Creek in 2018 was not

resampled in 2019, but was detected in 2020 at Bishop Pass, approximately 40 linear km south of Mono Creek. A new male was also detected by scat on the San Joaquin Ridge in the Mammoth Lakes study area in 2020.

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 sympatric carnivore species, will be critical to informing conservation planning. Our camera survey methods appear 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 over 100 linear km south of where the subspecies was thought to persist prior to this study. In addition, our findings demonstrated the prevalence of Pacific martens, a forest-associated species, in barren alpine habitat in winter. 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 highly suitable habitat for SNRF and wolverines.

This report details our activities during September 2018–December 2020.

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. By contrast, our study focuses on detecting carnivore presence in the highest-elevation, most barren regions of the range where few if any systematic carnivore surveys have occurred. 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.

SNRF are a species of particular interest due to their endangered status and the paucity of information about their current distribution. SNRF once ranged throughout the high elevations of the Sierra Nevada from the Lake Tahoe Basin to Mt. Whitney (Grinnell et al. 1937; Perrine et al. 2010). Today, researchers believe the highest density of the Sierra Nevada Distinct

Population Segment (DPS; USFWS 2015) of the SNRF is concentrated around Sonora Pass north of Yosemite National Park (Figure 12; Statham et al. 2012; Quinn et al. 2019). Beginning in 2012, several individuals from an apparently unrelated red fox population, likely originating in Nevada's Great Basin, immigrated into the DPS in the vicinity of Sonora Pass and bred with SNRF females (Quinn et al. 2019). Today, the genetic structure of the SNRF population in the Sierra Nevada is considered admixed due to the introduction of genetic material from these immigrant foxes (Sierra Nevada Red Fox Conservation Advisory Team 2022). Citing concerns about small population size, inbreeding depression, and potential negative consequences from outbreeding with immigrant red foxes, the USFWS recently listed the DPS as federally endangered (USFWS 2021). In 2018, we detected at least three SNRF in Mono Creek (Hatfield et al. 2021). This discovery greatly expanded the known contemporary distribution of the subspecies. Furthermore, a male SNRF detected near Sonora Pass in 2017 was detected in Mono Creek in 2018, demonstrating a dispersal of more than 120 linear km and suggesting that some connectivity exists between these occupied areas.

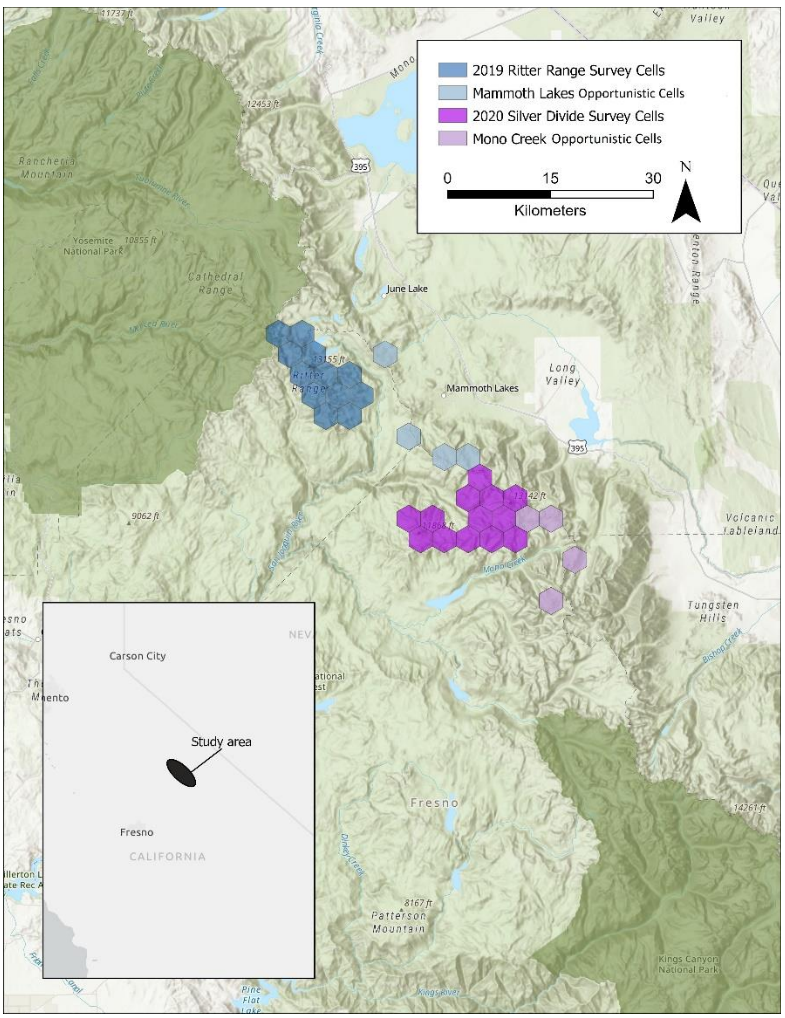

Figure 1. Map of 2019-2020 alpine mesocarnivore study area in the Sierra Nevada, California, including systematic survey cells and opportunistic cells.

In 2019 and 2020, our primary study objective was to detect SNRF and other alpine mesocarnivores that reside in or disperse through the Ritter Range and the Silver Divide, areas of potential habitat that lie to the north of the Mono Creek study area (Figure 1). A secondary objective was to better characterize SNRF occupying the Mono Creek study area by continuing to monitor their presence via cameras and obtaining genetic samples via scat to estimate the number of individuals present and the approximate boundaries of their distribution.

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 and 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.

Systematic Camera Surveys

Study Areas

We selected the Ritter Range and the Silver Divide as the focal areas for our systematic camera surveys in 2019 and 2020 based on high habitat suitability for SNRF (Cleve et al. 2011) and proximity to areas where SNRF had been detected recently.

The Ritter Range is a series of highly metamorphosed volcanic peaks extending from the southern border of Yosemite National Park to the confluence of Fish Creek with the Middle and North Forks of the San Joaquin River (Figure 1). The study area contained alpine and subalpine habitat characterized by krummholz, open meadow systems, and natural lakes, as well as mid elevations dominated by mature conifer forest.

The Silver Divide is a drainage divide separating the Fish Creek and Mono Creek watersheds (Figure 1). The divide is primarily granitic, but otherwise the study area contained habitats similar to those found in the Ritter Range.

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 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 camera placements in the Ritter Range and Silver Divide were located on passes. Other cameras were located on windswept ridges, knolls, or other features that typically accumulated minimal snow, or along trails likely to be used by wildlife.

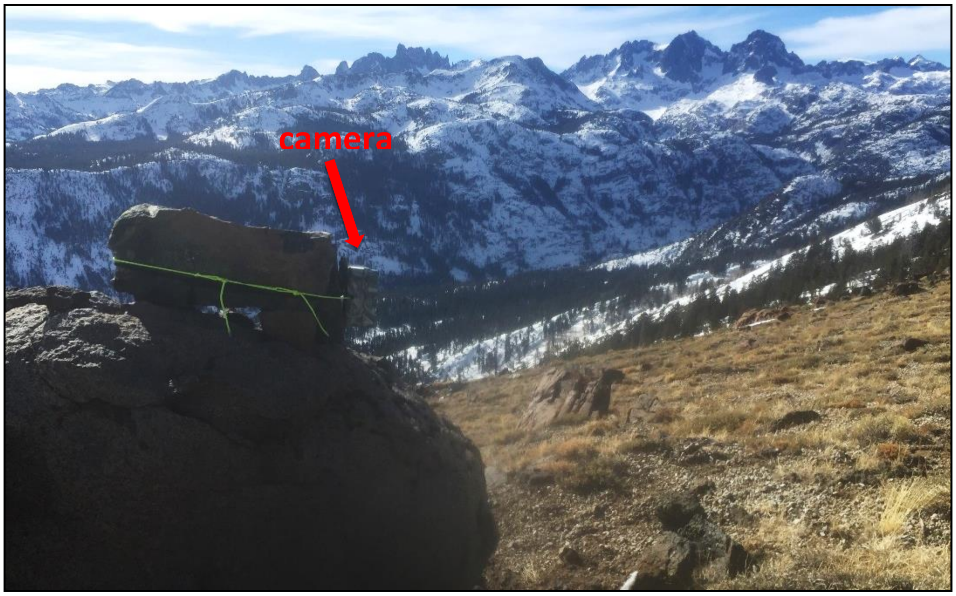

Figure 2. A camera sampling site on the San Joaquin Ridge near Mammoth Lakes, Sierra Nevada, California.

We deployed Reconyx motion detection cameras (Reconyx, Holmen, Wisconsin, USA) with commercial scent lure (Gusto, Minnesota Trapline Products, Pennock, Minnesota, USA) placed 5 m away from each camera to attract carnivores. We attached cameras with bungee cord to large boulders or trees (Figure 2) and oriented the camera lenses to within 30 degrees of north to minimize direct sun exposure that can cause images to have substantial glare. We programmed camera triggers at the highest 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. If a camera was buried by snow and could not be located, we placed a new camera in a snow-free spot in the vicinity of the buried camera so that the sample point remained a functional part of the survey.

In 2019, we deployed 24 cameras across 12 grid cells on both the east and west sides of the Ritter Range at elevations from 2,851 m to 3,731 m. Cameras sampled barren alpine and subalpine forest habitat types. We added eight cameras to replace cameras buried by snow in the Ritter Range in 2019. In 2020, we deployed 26 cameras across 13 grid cells on the crest and north side of the Silver Divide, as well as on adjoining portions of the Sierra Crest between McGee Pass and Duck Pass. Cameras were deployed at elevations between 3,150 m and 3,693 m in barren alpine and subalpine forest habitat types. We did not replace or add any cameras in the Silver Divide in 2020.

Opportunistic Cameras

Study Areas

The Mono Creek study area was adjacent to Rock Creek and McGee Creek and east of Lake Thomas Edison (Figure 1). Mono Creek bisected this study area with the Silver Divide to the north and the Mono Divide to the south. Each divide comprises a series of granite peaks and ridges enclosing hanging basins with lake and meadow complexes.

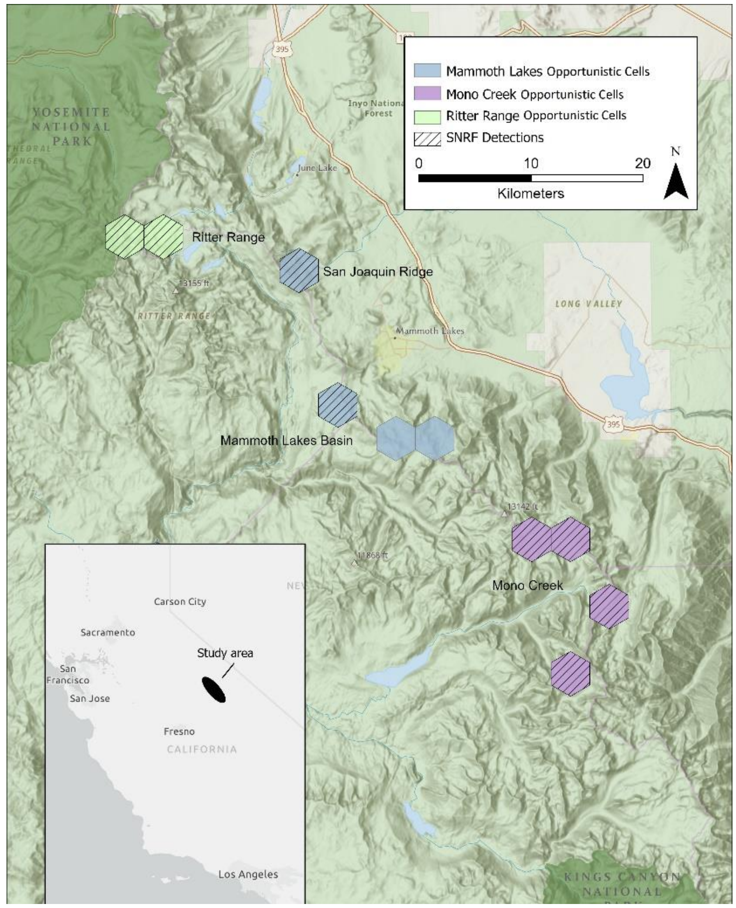

Figure 3. Map of opportunistic camera locations in 2019 and 2020 and cells where opportunistic cameras have detected SNRF in the Sierra Nevada, California.

The Mammoth Lakes study area comprised the Mammoth Lakes Basin and the San Joaquin Ridge (Figure 1). The Mammoth Lakes Basin is a drainage south of Mammoth Lakes, California, roughly equidistant between the Ritter Range and Mono Creek study areas. A volcanic ridge called the Mammoth Crest encloses a north-facing basin characterized by montane mixed-conifer forest and containing several small lakes. The San Joaquin Ridge is a volcanic ridge comprising the Sierra Crest between the towns of Mammoth Lakes and June Lake.

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 species of interest, or in areas that were likely to remain windswept and had reasonable year-round access. Opportunistic cameras were also 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 only present notable species detections from opportunistic cameras.

In the Mono Creek study area, we maintained opportunistic cameras in six locations where we detected SNRF in 2018: Steelhead Pass, Crocker Col, Mt. Starr Ridge, Trail Pass, Mono Pass, and Gabbot Pass (Figure 3). These cameras were placed in barren alpine habitat at elevations from 3,467 m to 3,738 m. We did not maintain a camera that had detected SNRF in Golden Creek; although the camera was located along a trail used by wildlife including SNRF, this low-elevation riparian location was likely to become buried in snow during winter.

In the Mammoth Lakes study area, we maintained opportunistic cameras in four 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 (Figure 3). We selected these locations because they appeared to be potential wildlife travel corridors that were easily accessible by field staff during day trips and were unlikely to become buried in snow.

We also maintained opportunistic cameras in the Ritter Range study area in two locations where SNRF were detected in 2019: Rodgers Lake and Marie Pass (Figure 3).

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 by 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 classified these as “unknown.” Animal detections of unknown species constituted a very small proportion of our results, and we do not report them here.

Figure 4. A SNRF scat collected at Mono Pass in the Sierra Nevada, California in November 2019.

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 mesocarnivore scats (Figure 4) 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, more recently, pelage color.

Red foxes have three distinct pelage colors: red, black (also called silver), and cross (characterized by a buff coat with darker fur running down the back and across the shoulders in the shape of a cross; Perrine et al. 2010). Recent research has enabled determination of coat color via genetic markers in scat samples, aiding in identification of individuals (C Quinn, UC Davis, personal communication 2022).

Partner Survey Efforts

Other agencies and researchers conduct surveys for SNRF in eastern Yosemite National Park and the Sonora Pass area. Concurrent with our efforts in 2019, Yosemite National Park used similar methods to deploy cameras in areas of the park adjacent to and extending north from the Ritter Range. In combination, the CDFW and Yosemite surveys in 2019 sampled a contiguous area extending over 70 linear km. CDFW Headquarters staff also deployed opportunistic cameras in the Sonora Pass study area, and scat surveys were conducted by scat dog detection teams in the Yosemite and Sonora Pass study areas.

IV. Results

Systematic Camera Surveys

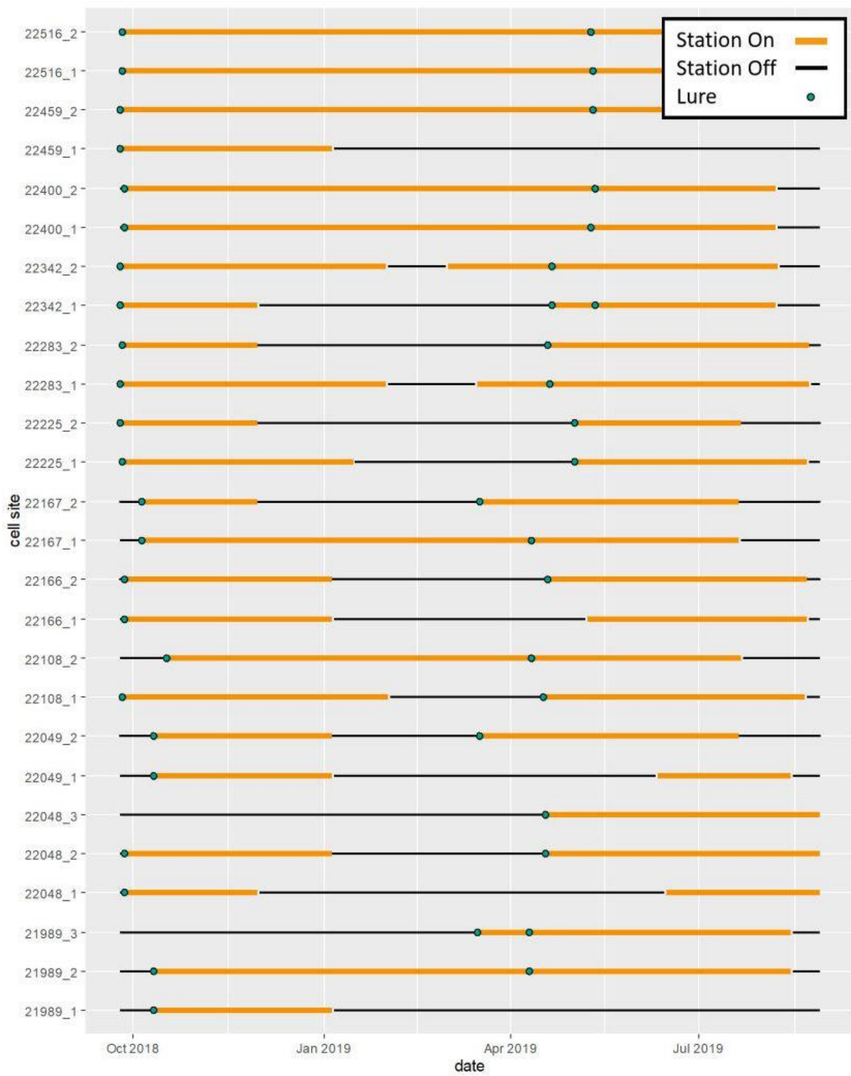

Figure 5. Operational and nonoperational periods for cameras in the Ritter Range study area, Sierra Nevada, California during the 2019 survey season.

<u>Ritter Range</u>

During our 2019 Ritter Range camera survey, 32 survey cameras were operational for 5,935 nights out of 8,280 nights deployed (72%; Figure 5). These tallies include 24 survey cameras deployed in October 2018 and an additional eight cameras deployed in spring 2019 to replace cameras that were buried in snow. The winter of 2018—2019 brought heavy snowfall throughout the Sierra; on April 1, 2019, regional snowpack was 164% of average (California Data Exchange Center data, <cdec.water.ca.gov>). In addition to burying some survey cameras, the deep snow also made winter fieldwork to reset and rebait cameras more demanding (Figure 6). Despite these challenges, we captured 189 bird detections and 620 mammal detections representing 13 bird species[1] and 21 mammal species, including 10 carnivore species (Table 1).

[1] Clark’s nutcracker, common raven, dark-eyed junco, gray-crowned rosy finch, mountain chickadee, mountain quail, pipit, ptarmigan, rock wren, Steller’s jay, sooty grouse, white-crowned sparrow, and Williamson’s sapsucker.

Figure 6. Winter fieldwork in the Ritter Range study area, Sierra Nevada, California in April 2019.

As in other study areas (Hatfield et al. 2020), Pacific martens and coyotes were the most commonly detected carnivores and the species detected at the highest proportion of sites (89 and 44 detections at 34% and 31% of sites, respectively). Notable detections include a kit fox at 3,303 m elevation in October 2018 (B. Cypher, California State University–Stanislaus, personal communication 2019; C. Quinn, UC Davis, personal communication 2019; B. Sacks, UC Davis, personal communication 2019), and a fisher at 3,294 m elevation in December 2018. We did not detect wolverines in the Ritter Range study area.

Figure 7. SNRF detected by a survey camera in the Ritter Range study area, Sierra Nevada, California in June 2019.

We detected SNRF at two cameras in the Ritter Range (Figure 7), located approximately 1.2 km apart at 3,220 m and 3,480 m elevation, respectively. Neither camera was located on a narrow pass, though both were on ridges that animals may use as travel corridors. The Rodgers Lake camera detected a SNRF in May. Both the Rodgers Lake and Marie Pass cameras captured photos of SNRF on the same day in June, about an hour apart. These latter detections may have been a single individual, as the two sites were separated by only 1.2 km.

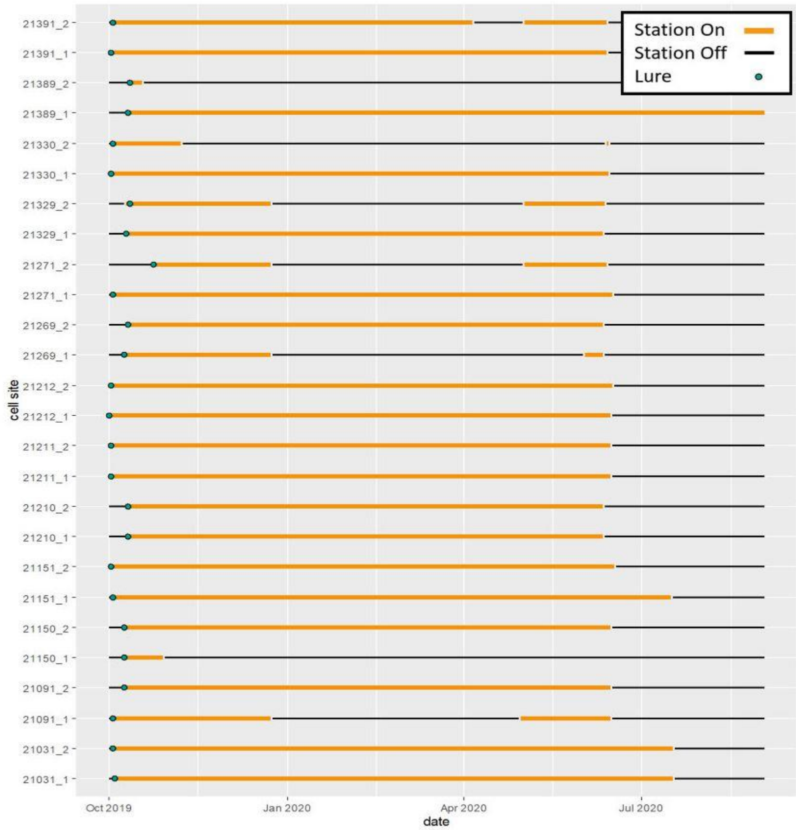

Figure 8. Operational and nonoperational periods for cameras in the Silver Divide study area, Sierra Nevada, California during the 2020 survey season.

Silver Divide

During our 2020 Silver Divide camera survey, 26 survey cameras were operational for 5,472 nights out of 6,731 nights deployed (81%; Figure 8). We captured 53 bird detections and 538 mammal detections representing seven bird species[2] and 15 mammal species, including seven carnivore species (Table 2). As with the Ritter Range survey, the most commonly and widely detected carnivores were Pacific martens and coyotes (45 and 100 detections at 58% and 77% of sites, respectively). We did not detect SNRF or wolverines in the study area. The most notable detection of the 2020 survey was a gray fox at an unexpectedly high elevation (3,393 m) in May 2020 (Figure 9).

Figure 9. Gray fox detected by a survey camera at 3,393 m in the Silver Divide study area, Sierra Nevada, California in May 2020.

The COVID-19 pandemic disrupted fieldwork during the winter and spring of 2020. In compliance with federal, state, county, and departmental regulations, we were not able to revisit or rebait survey cameras in the Silver Divide study area. Although snowpack was relatively low in 2020 (58% of April

[2] Clark's nutcracker, dark-eyed junco, gray-crowned rosy finch, pipit, ptarmigan, rock wren, and sooty grouse.

1 average, California Data Exchange Center data, <cdec.water.ca.gov>), eight out of 26 cameras were buried in snow or otherwise nonoperational for extended periods (Figure 8), which we did not discover until we retrieved the cameras in June and July 2021. The number and diversity of detections were nonetheless comparable to previous survey seasons.

Table 1. Mammal detections during 2019 in the Ritter Range study area, Sierra Nevada, California.

Species	Order	Detections	Sites
Pacific marten	Carnivora	89	11 (34%)
Coyote	Carnivora	44	10 (31%)
Long-tailed weasel	Carnivora	26	7 (22%)
American black bear	Carnivora	19	5 (16%)
Bobcat	Carnivora	6	4 (13%)
Red fox	Carnivora	3	2 (6%)
Mountain lion	Carnivora	3	1 (3%)
American badger	Carnivora	2	2 (6%)
Fisher	Carnivora	1	1 (3%)
Kit fox	Carnivora	1	1 (3%)
Yellow-bellied marmot	Rodentia	93	11 (34%)
Douglas squirrel	Rodentia	54	7 (22%)
Chipmunk *sp.*	Rodentia	45	6 (19%)
Golden-mantled ground squirrel	Rodentia	21	4 (13%)
Bushy-tailed woodrat	Rodentia	4	2 (6%)
Porcupine	Rodentia	3	2 (6%)
Mouse *sp.*	Rodentia	1	1 (3%)
White-tailed jackrabbit	Lagomorpha	105	8 (25%)
American pika	Lagomorpha	75	6 (19%)
Mule deer	Artiodactyla	20	6 (19%)
Sierra Nevada bighorn sheep	Artiodactyla	5	1 (3%)

Table 2. Mammal detections during 2020 in the Silver Divide study area, Sierra Nevada, California.

Species	Order	Detections	Sites
Coyote	Carnivora	100	20 (77%)
Pacific marten	Carnivora	45	15 (58%)
American black bear	Carnivora	17	7 (27%)
Bobcat	Carnivora	13	6 (23%)
American badger	Carnivora	3	1 (4%)
Gray fox	Carnivora	1	1 (4%)
Short-tailed weasel	Carnivora	1	1 (4%)
Chipmunk *sp*.	Rodentia	73	14 (54%)
Golden-mantled ground squirrel	Rodentia	49	13 (50%)
Douglas squirrel	Rodentia	31	14 (54%)
Yellow-bellied marmot	Rodentia	31	12 (46%)
Bushy-tailed woodrat	Rodentia	25	3 (12%)
Belding's ground squirrel	Rodentia	3	2 (8%)
White-tailed jackrabbit	Lagomorpha	35	6 (23%)
American pika	Lagomorpha	29	5 (19%)

Figure 10. Cross-pelage SNRF detected by an opportunistic camera in the Mono Creek study area, Sierra Nevada, California in June 2019.

Opportunistic Cameras

Opportunistic cameras in the Mono Creek study area continued to photograph SNRF during 2018, 2019, and 2020 (Figure 10). In October 2018, a SNRF triggered a camera on Gabbot Pass at 3,738 m, extending the area of known SNRF occurrence in Mono Creek approximately 6 km farther southwest than previous detections[3]. We obtained the first daytime detections of SNRF in our study areas on June 9, 2019 on both the Steelhead Pass and Trail Pass cameras. In the Mammoth Lakes study area, one camera detected a SNRF in July 2019 near the northwest end of the Mammoth Crest above Mammoth Pass and McCleod Lake. One camera on the San Joaquin Ridge detected a SNRF in March 2020.

In reviewing opportunistic camera detections from prior years, we identified a fisher photographed on Mammoth Pass in 2016. Prior to this detection, fishers were not known to occur east of the Sierra Crest (Tucker et al. 2012; J. Tucker, USFS, personal communication 2022).

Scat Surveys

In 2019, we collected 179 scat samples (133 from the Mono Creek study area, 29 from the Silver Divide study area, 11 from the Ritter Range study area, and six from other locations in the Sierra) of which seven were SNRF (Figure 11; Table 3). All SNRF samples contained the marker for red pelage. Four of the SNRF samples were from the Mono Creek study area and came from two individuals, a male and a female, both of which were sampled in that study area in 2018. A female SNRF sampled in Mono Creek in 2018 was not re-sampled in 2019. One SNRF scat collected in the Virginia Lakes drainage east of Yosemite National Park was assigned to a male last sampled by Yosemite National Park staff in the same area in 2017 (not shown in Figure

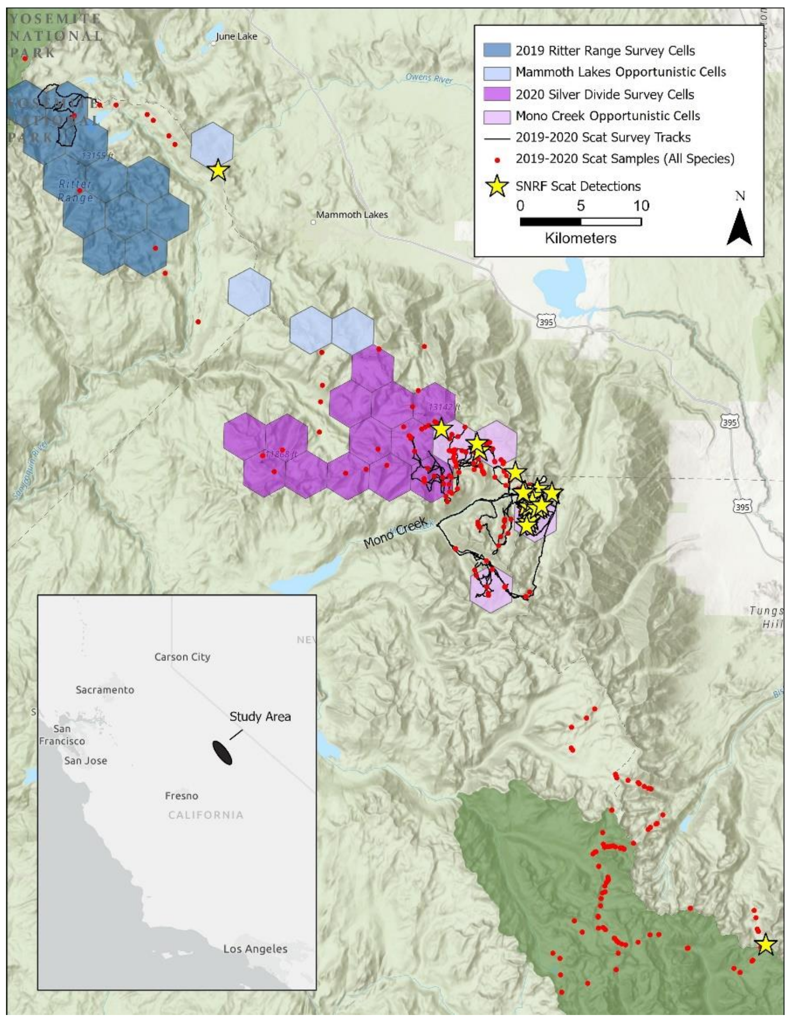

Figure 11. Map of scat surveyors' tracks, scat samples collected, SNRF scat detections, and cells with cameras within the study area in the Sierra Nevada, California in 2019 and 2020.

[3] This detection was not discovered until summer 2019, and is therefore included in this report.

11; Virginia Lakes is approximately 73 linear km northeast of Mono Creek). Individual identification was not possible for two SNRF samples from Mono Creek study area due to insufficient integrity of genetic material in the samples. We did not obtain genetic samples from SNRF in the Ritter Range or Mammoth Lakes study areas in 2019.

Table 3. Scat samples collected by CDFW in the Sierra Nevada, California during 2019, in order of abundance.

Species	Scats Collected	Proportion of Samples
Pacific marten	74	41.3%
Coyote	59	33.0%
Bobcat	11	6.1%
Red fox	7	3.9%
Mountain lion	2	1.1%
Gray fox	2	1.1%
Domestic dog	1	0.6%
Unable to determine	23	12.8%
Total	179	100.0%

In 2020, we collected 251 scat samples (124 from the Mono Creek study area, 102 from the 2021 Goddard Divide study area, 13 from the Silver Divide study area, four from the Mammoth Lakes study area, and eight from other locations in the Sierra), of which 17 were SNRF (Figure 11; Table 4). All SNRF samples contained the marker for red pelage. Fourteen of the SNRF samples were from the Mono Creek study area, one was from the San Joaquin Ridge in the Mammoth Lakes study area, where an opportunistic camera detected a SNRF in March 2020, and two were collected opportunistically on Bishop Pass on the border of our 2021 Goddard Divide study area. Individual identification was not possible for five of the samples from the Mono Creek study area due to insufficient integrity of genetic material in the samples. The remaining nine samples from Mono Creek were from the male and one of the females detected in 2018, and their two offspring, a male and a female. The San Joaquin Ridge sample was from a male with Great Basin ancestry (Quinn and Sacks 2022), possibly an immigrant to the study area. The Bishop Pass samples were from a female that was not detected in 2019 but was detected in 2018 in the Mono Creek study area, approximately 40 linear km north of Bishop Pass.

Table 4. Scat samples collected by CDFW in the Sierra Nevada, California during 2020, in order of abundance.

Species	Scats Collected	Proportion of Samples
Coyote	110	43.8%
Pacific marten	56	22.3%
Red fox	17	6.8%
Bobcat	4	1.6%
Gray fox	3	1.2%
Domestic dog or gray wolf	2	0.8%
Mountain lion	1	0.4%
American black bear	1	0.4%
Yellow-bellied marmot	3	1.2%
Unidentified prey species	7	2.8%
Unable to determine	47	18.7%
Total	251	100.0%

Partner Surveys

Cameras in Yosemite National Park photographed SNRF in three new locations during 2019 and 2020, including the first detections in Yosemite south of Tioga Road since the time of Grinnell et al. (1937). Scat dog detection teams detected one SNRF scat in an area near previous photo detections (M. McDonald, Yosemite National Park, personal communication 2020). Our collaborators with CDFW Headquarters and UC Davis also continued to detect SNRF by camera and scat in areas where they are known to occur near Sonora Pass (C. Stermer, CDFW, personal communication 2020, C. Quinn, UC Davis, personal communication 2020).

V. Discussion

Our results confirm that many carnivore species considered native to the Sierra Nevada occur at the highest elevations of the range in winter. During this study period we detected eight of the 13 taxa documented by Zielinski et al. (2005). We did not detect five species present in that

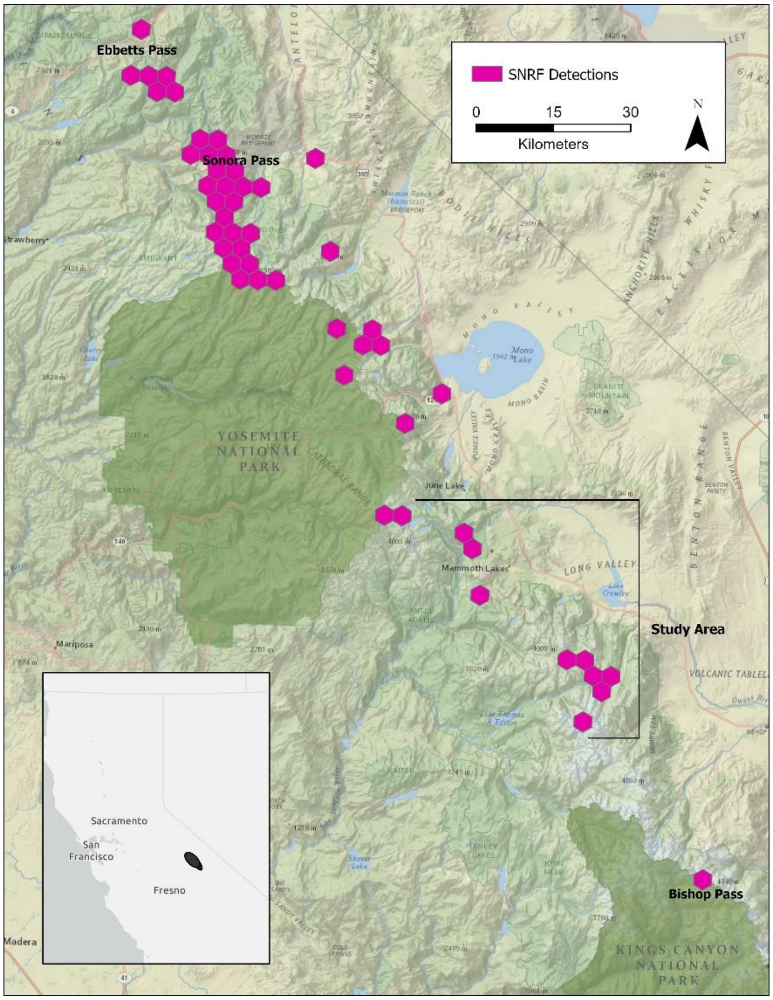

Figure 12. Map of cells where SNRF have been detected since 2010 throughout the Sierra Nevada, California, including in areas adjacent to our study area.

study (Virginia opossum, striped skunk, Western spotted skunk, raccoon, and ringtail[4]), and detected two species (SNRF and kit fox) not detected by Zielinski et al. (2005). During our systematic surveys, coyotes and Pacific martens were the most detected carnivores, both in terms of number and distribution of detections. Whereas coyote presence in the alpine in winter is well documented (Gantz 1990, Knowlton and Gese 1995, Gese et al. 1996, Shivik et al. 1996, Shivik et al. 1997, Dowd et al. 2013), Pacific martens in the Sierra Nevada are consistently represented in the literature as mature forest specialists (Zielinski et al. 2005, Moriarty et al. 2011, Zielinski et al. 2015, Martin et al. 2021) that avoid open areas (Koehler et al. 1975, Spencer et al. 1983), particularly in winter (Spencer et al. 2015, Zielinski et al. 2015). In our study, Pacific martens were more frequently and broadly detected than other carnivore species (e.g., American badger, long-tailed weasel) that are known to use alpine habitat (Grinnell et al. 1937, Quick 1951, Lindzey 1994, Newhouse and Kinley 2000, Zielinski et al. 2005). Our study suggests that Pacific martens are widespread and common in winter in barren habitat at the highest elevations of the Sierra Nevada. It is possible that martens have recently expanded their habitat niche to include the alpine, perhaps as a result of a warming climate or due to habitat loss from wildfires in lower elevation forests. A more likely explanation is that year-round marten presence in the alpine was not detected previously because prior studies did not sufficiently survey high elevations in winter.

[4] We detected two of these species (Western spotted skunk and ringtail) during other study periods not summarized in this report (Hatfield et al. 2020, CDFW unpublished data). Virginia opossums, striped skunks, raccoons, and ringtails typically occur at elevations lower than our study area (Zielinski et al. 2005).

Other notable carnivore detections during this study period were a kit fox at 3,303 m in the Ritter Range study area in October 2018, a fisher at 3,294 m in the Ritter Range study area in December 2018, and a gray fox 3,393 m in the Silver Divide study area in May 2020. These species are not typically expected to use alpine habitat. The elevation range of the kit fox is thought to be between 400 m and 1,900 m (Cypher and List 2014). Fishers select for dense, mature conifer forests at both the landscape and home-range scale (Spencer et al. 2015). The nearest fisher detection to our study area documented by USFS surveys between 2011 and 2018 was about 25 km away to the southwest (J. Tucker, USFS, personal communication 2019). Fishers have been detected as high as 3,134 m elsewhere in the Sierra, but most previous detections in the vicinity of the Ritter Range study area were concentrated in montane forests below 2,140 m (Spencer et al. 2015). Historical surveys of gray foxes in California found them to be most abundant at elevations between 1,150 m–1,525 m (Grinnell et al. 1937) with a mean elevation of detections of approximately 1,250 m (Zielinski et al. 2005). However, according to long-term carnivore monitoring data from the southern Sierra Nevada, gray fox occupancy above 2,000 m has increased by 25–30% since 2012 (Tucker et al. 2019). The kit fox, fisher, and gray fox detections during our survey presumably represent anomalous exploratory movements or dispersals by single individuals rather than selection for alpine habitat, but are still of interest given the elevational distance from areas where these species are typically found.

Recent photo and scat detections of SNRF now appear to be distributed relatively continuously along the Sierra Crest between Ebbetts Pass and Bishop Pass, with maximum linear distances between detections of less than 30 km (Figure 12). SNRF home ranges can be as large as 135 km^2, and very long distance movements (up to 395 km; Ables 1965) have been reported in the literature for other red fox subspecies (Sierra Nevada Red Fox Conservation Advisory Team 2022). While it is possible that cameras in multiple locations have photographed a small number of SNRF traveling between population centers, the span of SNRF detections in the Sierra Nevada could be interpreted as representing a continuous population. The detection of the same individual in Sonora Pass and later in Mono Creek (a linear distance of more than 120 km) indicates that these study areas have some connectivity, but it is unknown whether this connectivity is occasional or regular.

During three consecutive years of intensive scat surveys in Mono Creek we detected only five individuals (Figure 13). Two of these individuals were sampled every year during 2018–2020. In 2020, two offspring of this pair were detected for the first time. Detections of the same individuals in multiple years, as well as detections of their offspring, indicate that there is a resident, reproducing population of SNRF in Mono Creek. The population size is likely very small, although the scarcity of samples could also reflect low detectability.

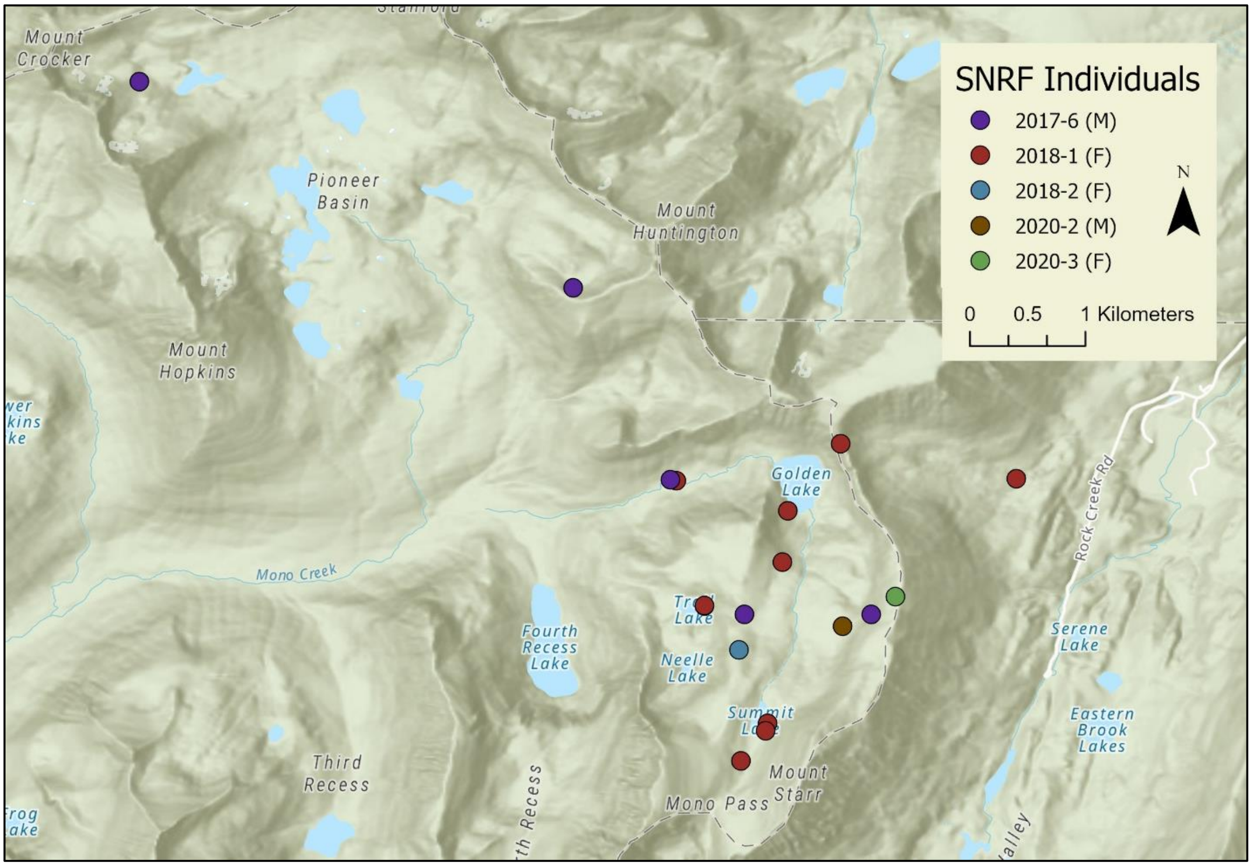

Figure 13. Known locations determined from scat samples of 5 individual SNRF in the Mono Creek study area, Sierra Nevada, California during 2018–2020.

All SNRF scat samples collected to date in our study area contained the marker for red pelage. Because foxes with red pelage are homozygous for that trait, two red parents cannot produce offspring with black or cross pelage. Therefore, the black-pelage juvenile fox shown in the cover photo of this report cannot have been produced by the red-pelage mated pair detected in the Mono Creek study area (C. Quinn, UC Davis, personal communication 2022). Furthermore, we have not yet collected scat samples from the cross-pelage SNRF photographed in the Mono Creek study area in 2019 (Figure 10). These results demonstrate that we have detected a minimum of nine SNRF individuals across our study areas by camera or scat since 2018 (see Hatfield et al. 2020 for 2018 scat detections), and that our noninvasive survey methods likely cannot be relied upon to produce a census of SNRF.

Repeated camera and scat detections of SNRF outside of the Mono Creek study area confirm that the distribution of the population in our study area extends beyond that watershed. The detection of the same female in the Mono Creek study area in 2018 and at Bishop Pass in 2020 suggests a dispersal movement because the linear distance between these areas (> 40 km) is more than three times greater than the diameter of the largest documented SNRF home range (135 km^2; Sierra Nevada Red Fox Conservation Advisory Team 2022) centered on the 2018 detection. We do not know when the female arrived at Bishop Pass, whether she is resident there, or whether other SNRF reside in that vicinity. The origin of a new individual detected on the San Joaquin Ridge is also difficult to interpret without further information: this individual had Great Basin ancestry with no discernible relationship to other individuals in the study area (Quinn and Sacks 2022), suggesting that it was an immigrant to the study area from an unrelated population of red foxes, likely the same population that has provided immigrants to the Sonora Pass study area since 2012. Alternatively, this individual could have immigrated from another unrelated red fox population, or could have been born in the study area to immigrant parents that have not yet been detected. Further scat surveys on the San Joaquin Ridge are warranted to collect additional samples from this and any other red foxes present in the area.

Our camera survey methods continue to be successful in detecting both common and purportedly rare carnivores, including SNRF. Both systematically and opportunistically placed cameras have produced unexpected detections of carnivores such as kit foxes, gray foxes, and fishers at elevations and in areas where they were not known to occur. Our surveys have also documented extensive use by Pacific martens of alpine habitat in winter, contrary to expectations from the literature of typical habitat selection by martens. Our results provide insight into the current distribution and dispersal range of multiple carnivore species, and demonstrate the diversity of the carnivore assemblage in the alpine Sierra Nevada.

Future Work

In fall 2020 we collaborated with Sequoia and Kings Canyon National Parks (SEKI) to deploy 29 cameras across 16 survey cells in the Goddard Divide study area. This region encompasses portions of the Glacier Divide, Evolution Group, Black Divide, Goddard Divide, LeConte Divide, and White Divide, areas of highly suitable habitat for SNRF located between 20–40 km south of the southernmost recent camera detections of SNRF and adjacent to the recent scat detection on Bishop Pass. In fall 2021, we again collaborated with SEKI to deploy 27 cameras across 14 survey cells in the Woods Creek study area, beginning at the southern border of the Goddard

Divide study area and continuing south along the Sierra Crest from Taboose Pass to Kearsarge Pass. Results from those surveys are still pending as of the writing of this report.

In future, we intend to continue surveying areas of SEKI that contain highly suitable potential habitat for SNRF. We will also maintain opportunistic cameras, both in locations where we have detected SNRF, and in other areas where year-round access is straightforward and we estimate a high probability of carnivore detections. We will continue to conduct scat surveys opportunistically throughout our study areas and systematically in areas where we have detected SNRF.

In addition to survey work, we are engaged in an ongoing effort to model density, occupancy, and habitat associations of carnivore species in our study area. This effort will help us to understand how carnivores use high-elevation habitats in the Sierra Nevada.

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