# A CONSERVATION STRATEGY FOR THE SIERRA NEVADA RED FOX

Prepared by the Sierra Nevada Red Fox Conservation Advisory Team | 2022

Photo courtesy of John Perrine

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# SIERRA NEVADA RED FOX CONSERVATION ADVISORY TEAM (SCAT)

The Sierra Nevada Red Fox Conservation Advisory Team (SCAT) is composed of 24 general members and an 11-person Executive Committee. This membership comprises representatives from the land and wildlife management agencies whose jurisdictions encompass the range of the Sierra Nevada red fox in California and Oregon, as well as experts in fields related to Sierra Nevada red fox conservation. The participating agencies and organizations are: the California Department of Fish and Wildlife (CDFW); California Polytechnic State University in San Luis Obispo (Cal Poly); Cascades Carnivore Project of Hood River, Oregon; the National Park Service (NPS); the Oregon Department of Fish and Wildlife (ODFW); Oregon State University (OSU); the United States Fish and Wildlife Service (USFWS); the United States Forest Service (USFS); the Mammalian Ecology and Conservation Unit at the University of California, Davis (UC Davis); and the Wildlife Ecology Institute of Helena, Montana.

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## SUGGESTED CITATION

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Photo courtesy of Nancy Burke

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# GLOSSARY

Throughout this document, we use terms that may be unfamiliar to some readers. We also employ some commonly understood terms (e.g., immigration) in a specific sense that requires clarification. Here we define these terms as they are applied in the Conservation Strategy.

***Admixture***

The presence in an individual of DNA from a genetically differentiated population or subspecies.

***Allele***

A distinct sequence of bases, nucleotides, or number of repeats occurring at a locus in the genome. A diploid genotype with 2 distinct alleles is heterozygous. A diploid genotype with 2 identical alleles (same allele inherited from both parents) is homozygous.

***Backcross***

Reproduction between a hybrid individual and a non-hybrid individual of one of its parental populations.

***F1 hybrid***

An offspring produced by parents of different subspecies (i.e., a first-generation hybrid).

***F2 hybrid***

An offspring produced by 2 F1 hybrid parents.

***Genetic effective population size (Ne)***

Equivalent to the number of breeding adults in an ideal, randomly breeding population that would result in the observed genetic diversity of a population and its rate of loss over time due to genetic drift.

***Genetic distance***

A measure of the degree of differentiation between population allele frequencies. Genetic distance increases with the length of time of isolation or, if populations are connected by gene flow, reflects the predominance of breeding within populations over that between populations. In either case, genetic distance increases faster in smaller populations due to genetic drift.

***Genetic drift***

Changes over time in the relative frequency of different alleles within a population. In small populations, genetic drift can result in the loss of alleles, reducing the genetic diversity of the population.

***Genetic load***

A reduction of the mean fitness of a population due to an increase in the proportion of deleterious (usually recessive) alleles present in that population.

***Genetic swamping***

Replacement of the native alleles of a population by foreign alleles.

***Heterozygosity***

The observed or estimated proportion of loci within an individual or population that is heterozygous; a heterozygous locus is one with 2 alleles present. Often used as a measure of genetic diversity.

***Hybridization***

The production of offspring by 2 individuals from genetically distinct species, populations, or subspecies; synonym of interbreeding, outbreeding.

***Immigration***

Establishment within a population of an individual from a genetically distinct population or subspecies (as distinct from introgression, which refers to the genetic consequences of immigration and subsequent interbreeding).

***Inbreeding***

Reproduction between closely related individuals, resulting in decreased heterozygosity.

***Inbreeding depression***

Reduced fitness of a population due to breeding between closely related individuals.

***Interbreeding***

The production of offspring by 2 individuals from genetically distinct species, populations, or subspecies; synonym of hybridization, outbreeding.

***Introgression***

The process by which an allele diffuses from 1 species or population into another via repeated generations of backcrossing following an outbreeding event.

***Local adaptation***

The evolution of a trait through selective pressure from the immediate environment, unshared by populations of the same species that inhabit different environments.

***Mitochondrial haplotype***

A particular sequence of mitochondrial DNA, which reveals maternal lineage.

***Outbreeding***

The production of offspring by 2 individuals from genetically distinct species, populations, or subspecies; synonym of hybridization, interbreeding.

***Outbreeding depression***

Reduced fitness of a population when breeding between genetically differentiated individuals results in loss of local adaptation, increased genetic load, or genetic incompatibilities.

***Reinforcement***

The addition of animals to an extant population via translocation.

***Reintroduction***

The establishment via translocation of a new population in an area of the species' historical range determined to be unoccupied.

***Translocation***

The capture, transport, and release of animals from one area to another for conservation purposes (reinforcement and reintroduction are examples).

Photo courtesy of Chaney Swiney

# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AR | anticoagulant rodenticide |
| ATV | all-terrain vehicle |
| BWRA | Bridgeport Winter Recreation Area |
| CDFW | California Department of Fish and Wildlife |
| CEQA | California Environmental Quality Act |
| CESA | California Endangered Species Act |
| CI | confidence interval |
| CLNP | Crater Lake National Park |
| DPS | United States Fish and Wildlife Service Distinct Vertebrate Population Segment |
| ESA | Endangered Species Act |
| GPS | global positioning system |
| IUCN | International Union for Conservation of Nature |
| LVNP | Lassen Volcanic National Park |
| MCMWTC | Marine Corps Mountain Warfare Training Center |
| MCP | minimum convex polygon |
| NEPA | National Environmental Policy Act |
| NPS | National Park Service |
| ODFW | Oregon Department of Fish and Wildlife |
| OHV | off-highway vehicle |
| OSU | Oregon State University |
| OSV | over-snow vehicle |
| PLCCC | public land cannabis cultivation complex |
| RHDV-2 | Rabbit Hemorrhagic Disease Virus serotype-2 |
| SCAT | Sierra Nevada Red Fox Conservation Advisory Team |
| SD | standard deviation |
| SNRF | Sierra Nevada red fox |
| SSA | United States Fish and Wildlife Service Species Status Assessment |
| UC Davis | University of California, Davis |
| USFS | United States Forest Service |
| USFWS | United States Fish and Wildlife Service |
| YNP | Yosemite National Park |

Throughout this document, we use the common metric abbreviations m (meters), km (kilometers), and kg (kilograms).

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Photo courtesy of Tim Hiller

# EXECUTIVE SUMMARY

The Sierra Nevada red fox (*Vulpes vulpes necator;* SNRF) is a montane subspecies of red fox native to California and Oregon. The distribution, abundance, and genetic diversity of some extant SNRF populations have declined substantially since the 1920s, elevating concern for the continued viability of the subspecies and prompting the development of this Conservation Strategy.

The conservation vision for the SNRF is the long-term persistence of viable populations of SNRF within their historical range, as well as the development and implementation of effective programs and actions for mitigating threats and monitoring the subspecies' distribution and population status. Building on the SNRF Conservation Assessment (Perrine et al. 2010), this Conservation Strategy summarizes current knowledge about the SNRF and proposes measures to guide researchers and managers toward achieving this vision.

The SNRF inhabits montane, subalpine, and alpine zones. Currently, 3 small, disjunct populations occupy limited portions of their historical range: in the Lassen Peak region, the Sierra Nevada, and the Oregon Cascades. The greatest known threats to the subspecies are small population sizes, isolation, and consequent inbreeding and low genetic diversity.

Progress in SNRF conservation is hindered by our limited understanding of several basic characteristics of extant SNRF populations, identified in section III.B.1. Information Needs: Tier 1. Although few field studies have been conducted, preliminary results suggest substantial differences between the ecological characteristics of SNRF populations and those of well-studied red fox populations in non-montane regions. Expanding systematic surveys and monitoring throughout the historical range are essential to accurately determine the current distribution, abundance, trend, viability, genetic diversity, and genetic structure of SNRF populations, as well as to locate den sites and to detect any additional populations that occur within the historical range. This information will be crucial to designing and implementing effective management.

In some cases, we have sufficient knowledge to recommend specific actions to benefit or restore SNRF populations. All evidence suggests that the Lassen population of SNRF is extremely vulnerable due to inbreeding and other consequences of small population size, and may become extirpated within a small number of generations. Therefore, we recommend development of a translocation feasibility assessment to address options for reinforcing the Lassen population as an emergency measure to prevent extirpation. Completing such an assessment will rely on answers to the questions posed in III.B.1. Information Needs: Tier 1, in particular the identification of potential source populations that are robust enough to withstand removals.

A translocation feasibility assessment should also evaluate translocation needs for other populations and unoccupied areas within the historical range. The most effective means of ensuring the long-term persistence of the SNRF will be to increase its abundance, geographic distribution, and genetic diversity such that populations are more resilient to threats, particularly in the context of climate change. While genetic rescue of the Lassen population is the most immediate priority, multiple translocation events may be required to restore adequate genetic diversity to SNRF populations throughout their range.

In addition to carefully planned translocations, numerous other management actions (detailed in section

III.C.1. Management Actions: Tier 1) may help mitigate known or potential threats to SNRF. Although specific habitat associations of the SNRF vary by region and are not thoroughly understood at this time, the subspecies is apparently restricted to montane, subalpine, and alpine zones. Land management practices that maintain these environments within their natural ranges of variation will likely benefit SNRF. In particular, projects that restore high-elevation meadow systems and retain forest understory structure will support small mammal populations, which provide important prey resources for SNRF. When possible, land and wildlife managers should work together to determine the potential impacts of recreation and land management activities near known SNRF den sites.

Public education to discourage littering and feeding wildlife, along with carnivore-proof trash disposal, may reduce the likelihood that SNRF become food-conditioned or habituated to humans. In turn, these measures may reduce instances of SNRF mortality due to vehicle strikes or potential rodenticide poisoning. As recreation increases in many areas occupied by SNRF, it will become more important to minimize negative interactions between SNRF and humans or pets. Where highways intersect SNRF habitat, options should be explored to create or improve wildlife crossing structures and otherwise mitigate the risk of vehicle strikes.

Dedicated research efforts are needed to determine any ecological and anthropogenic factors that limit the ability of SNRF populations to recover and persist. Enumerated in section III.B.2. Information Needs: SNRF Ecology and Potential Threats, these research objectives include improving our understanding of SNRF habitat requirements and den-site selection, assessing competition with or predation of SNRF by sympatric carnivores, determining whether SNRF fitness is affected by limited food availability, and examining the behavioral or demographic consequences of anthropogenic disturbances to SNRF.

Finally, it is vital that agencies and their partners continue to look beyond the boundaries of disciplines and regional jurisdictions, coordinating efforts and sharing results. Achieving the conservation vision for the SNRF will require a sustained commitment to collaboration between agencies and researchers across the subspecies' entire range.

Photo courtesy of Steve Cosner

# I. INTRODUCTION

The Sierra Nevada red fox (*Vulpes vulpes necator*; SNRF) is a subspecies of red fox native to California and Oregon. Prior to European colonization, the SNRF was distributed throughout much of the Sierra Nevada, Cascades, and Klamath Mountains in alpine, subalpine, and montane zones (Figure 1; Bailey 1936; Grinnell et al. 1937; Hall 1981; Perrine et al. 2010; Sacks et al. 2010a). By the mid-twentieth century, range contractions, small population sizes, and genetic isolation prompted concern for the continued viability of the subspecies in many areas of its range. Currently, the SNRF persists in 3 geographically distinct populations, located in the Lassen Peak region, the Sierra Nevada, and the Oregon Cascades. The Sierra Nevada population is recognized by USFWS as a Distinct Population Segment (DPS), and is listed as endangered under the Endangered Species Act (ESA; USFWS 2021). Contemporary efforts to determine the current distribution and status of the SNRF in California and Oregon began in the 1990s and are ongoing.

The "best available science" is often the gold standard supporting conservation decisions. In the decade following the publication of a Conservation Assessment for the SNRF (Perrine et al. 2010), the best available science for this elusive montane canid has progressed enough to warrant a renewed focus on strategic planning to conserve the subspecies. A collaborative forum of wildlife managers, land managers, researchers, and conservation organizations—the Sierra Nevada Red Fox Conservation Advisory Team (SCAT)—convened beginning in 2018 to develop a Conservation Strategy to promote SNRF research and recovery range-wide. This document, hereafter referred to as the Strategy, is the result of that effort.

## I.A. PURPOSE OF THE STRATEGY

The intent of the Strategy is to: 1) encapsulate the most up-to-date knowledge of SNRF biology, ecology, distribution, and population status; 2) guide the foreseeable future of SNRF conservation by providing recommendations for urgent research, management, and planning priorities; and 3) identify where uncertainty or lack of information hinders our understanding and ability to make educated conservation decisions.

Because the 3 SNRF populations differ notably in their history, ecology, and level of conservation concern, we discuss considerations specific to each population. Where possible, we identify the relevant spatial scale (study area, habitat type, population, or range-wide) for the information and recommendations we provide.

The Strategy is not a regulatory document. The recommendations contained herein do not entail any formal requirements or obligations for any agency. The Strategy is also not a recovery plan: we do not specify quantifiable recovery criteria or targets, but rather steps that may enable planners to develop such criteria in the future. Finally, the Strategy is not a Conservation Assessment, but builds on the assessments completed by Perrine et al. (2010) and by USFWS (2015, 2018). For a thorough review of general red fox biology and ecology, we refer readers to these previous assessments. In the Strategy, we provide new information learned since 2010 regarding the distribution, habitat use, movements, abundance, genetic diversity and structure, morphology, reproduction, mortality, and diet of extant SNRF populations or individuals.

Figure 1. Estimated current distribution of the SNRF across its range, based on remote camera and scat surveys and detections from 1992–2020, relative to estimated historical distribution (Bailey 1936; Grinnell et al. 1937). Currently, the SNRF persists in 3 geographically distinct populations, located in the Lassen Peak region, the Sierra Nevada, and the Oregon Cascades. The Sierra Nevada population is recognized by USFWS as a Distinct Population Segment (DPS), and is listed as endangered under the Endangered Species Act (ESA; USFWS 2021). Contemporary efforts to determine the current distribution and status of the SNRF in California and Oregon began in the 1990s and are ongoing.

## I.B. PLANNING IN THE FACE OF UNCERTAINTY

Many aspects of SNRF biology remain poorly understood. Fundamentally, we do not know with precision how many SNRF exist range-wide, where they do and do not occur, or the entire suite of factors that threaten their viability. Without this knowledge, it is difficult to predict how future changes in climate, habitat, or management will affect SNRF populations, or what management interventions are most urgently needed to conserve them. Data collected each year expand and alter our understanding, but because we are still collecting basic information, these new results often raise additional questions. In most study areas, continuing research relies on arduous fieldwork in remote environments. Even where SNRF are known to exist, obtaining adequate probabilities of detection or representative sample sizes can be problematic due to their small numbers, large home-range sizes, and elusive behavior. In short, the backdrop for SNRF conservation is one of pervasive uncertainty.

Nonetheless, we have sufficient concern that some SNRF populations are imminently vulnerable to extirpation to undertake this planning effort and to advocate for sustained attention to SNRF conservation throughout their range. Our concern is based on evidence found in literature and data, both published and unpublished, from a diversity of credible sources. Recent findings indicate that most extant SNRF populations are small and isolated. Further evidence suggests that most or all populations have experienced declines in population size, genetic diversity, and distribution over the past century. We believe this Strategy is crucial and timely to address these and other potential threats to SNRF persistence, particularly in the context of anticipated climate-driven changes to SNRF habitat and community ecology.

Our approach relies on identifying and investigating uncertainties. Throughout the Strategy, we acknowledge where lack of information limits our ability to make inferences or recommendations. We occasionally offer evidence-based speculation that encompasses broad ecological theory or relevant biological systems (e.g., red fox populations in other regions), but we indicate clearly the level of confidence underlying these statements.

A primary focus of the Strategy is a detailed inventory of the research questions most likely to advance SNRF conservation, given what we do and do not know about the subspecies. In terms of management interventions, we endorse the immediate implementation only of those that are likely to benefit the SNRF with minimal risk of causing individual mortality or population-level declines in survival or reproduction. For all other management options, we specify the information gaps that must be filled before such actions can be considered or carried out. Finally, we recognize that this Strategy, while necessary and valuable, is a simply a first step toward achieving our conservation vision for the SNRF[1], and suggest clear objectives for continued strategic planning.

## I.C. HOW TO USE THE STRATEGY

Because our knowledge about the SNRF is constantly increasing, the Strategy is designed to be a living document. Research findings presented at annual meetings of the SNRF Working Group will be appended to the Strategy if they do not necessitate revisions of the existing text. As new information is gathered, the SCAT will undertake periodic formal reviews of the Strategy. When a majority vote determines that revisions are needed,

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[1] See section I.D. Vision, Goals, and Objectives.

the SCAT will amend the appropriate sections of the Strategy and inform relevant partners and stakeholders of the specific updates that were incorporated.

The Sierra Nevada Red Fox Conservation Strategy website (https://wildlife.ca.gov/Conservation/Mammals/Sierra-Nevada-Red-Fox/Strategy) will be maintained by CDFW to include the most recent versions of all text and figures. Particularly when using the Strategy to inform management decisions that may impact the SNRF, we encourage readers to download the most recent version of the Strategy directly from this website rather than relying on previous versions.

Conservation planning for the SNRF is supported by several external projects in addition to the Strategy. These include 2 range-wide distribution models and a genetic management plan for the SNRF. Preliminary results from the distribution models are summarized in this document. Final results from these models, as well as relevant results from the genetic management plan, will be presented in future addenda to the Strategy.

Management recommendations included in the Strategy should be implemented in an experimental framework. Such an adaptive management approach will allow managers to evaluate the effectiveness of any actions, and revise and retest management hypotheses accordingly. We encourage flexibility and caution in any management decisions relevant to SNRF or their habitat, reminding our readers that although we present what is currently the best available science, the information may be incomplete and subject to revised interpretation as we continue to learn more about SNRF ecology.

# I.D. VISION, GOALS, AND OBJECTIVES

Following the *Guidelines for Species Conservation Planning* developed by the International Union for Conservation of Nature (IUCN 2017), we began our planning process by crafting a vision statement to define the desired future condition of the species:

## I.D.1. VISION STATEMENT

The conservation vision for the SNRF is the long-term persistence of viable populations of SNRF within their historical range, as well as the development and implementation of effective programs and actions for mitigating threats and monitoring the subspecies' distribution and population status.

We have developed 5 overarching goals integral to the realization of this vision, along with the underlying objectives that will contribute to meeting each goal.

## I.D.2. GOALS AND OBJECTIVES

1. **Identify, secure funding for, and complete research, analyses, and monitoring needed to address uncertainties and inform management interventions.**
    a. Develop and implement survey and monitoring methods that provide sufficient detection probabilities for SNRF and enable estimation of population parameters
    b. Conduct studies to investigate ecological factors that may affect SNRF conservation
    c. Develop a long-term adaptive approach for updating SNRF distribution and habitat information
2. **Ensure that viable populations of SNRF persist within the historical range.**
    a. Ensure that extant populations of SNRF are viable, genetically diverse, and resilient to chance deleterious events and environmental changes

    b. Maintain or increase the distribution of SNRF within the historical range to enhance connectivity and resilience
    c. Maintain the functional role, natural ecology, and behavior of SNRF
    d. Maintain or increase the quality of available habitat
3. **Mitigate individual- and population-level threats to SNRF.**
4. **Educate the public to reduce negative human-SNRF interactions and build popular support for SNRF conservation.**
5. **Continue collaborative conservation planning.**
    a. Complete a translocation feasibility assessment, including an assessment of captive breeding feasibility
    b. Continue genetic research to inform a range-wide genetic management plan
    c. Streamline management, storage, and sharing of SNRF data among agencies and researchers
    d. Regularly evaluate and update this Strategy
    e. Ensure that SNRF conservation is conducted and supported at the range-wide level

These goals and objectives represent our current priorities for achieving the conservation vision for the SNRF. Where we lack the information to establish well-defined objectives (such as with Goal 3 above), we use general language as a placeholder to allow for more specific interpretation as we collect new data (e.g., direct evidence of an explicit threat to SNRF population viability). We anticipate the need to reconsider these goals and objectives periodically, and may modify them to represent the most effective pathway to SNRF conservation.

# I.E. ORIGIN AND DEFINITION OF THE SNRF

## I.E.1. EVOLUTIONARY ORIGINS

The red fox (*Vulpes vulpes*) first colonized North America via the Bering land bridge 500,000 to 300,000 years before present (Aubry et al. 2009; Statham et al. 2014). Other than a small amount of genetic exchange between populations in Asia and Alaska approximately 50,000 years before present (during the Wisconsin glaciation), North American red foxes have remained evolutionarily distinct from Eurasian red foxes (Aubry et al. 2009; Statham et al. 2014; Sacks et al. 2018). Within North America, red foxes comprise 3 major lineages corresponding to Pleistocene refugia in Alaska (Beringia), eastern Canada, and the western United States (hereafter, U.S.; Aubry et al. 2009; Sacks et al. 2018). The lineage in the western U.S. is subdivided into 3 montane subspecies (Cascade red fox, *V. v. cascadensis*; Rocky Mountain red fox, *V. v. macroura*; and Sierra Nevada red fox) and 1 non-montane subspecies, the Sacramento Valley red fox (*V. v. patwin*; Seton 1929; Grinnell et al. 1937; Sacks et al. 2010a). The 3 montane subspecies became isolated from one another in their respective mountain ranges during the Holocene (Figure 2), but likely share ecological adaptations to their similar habitats and climatic zones.

Since the time of European colonization, the genetic history of red foxes in the western U.S. has been complicated by natural and human-mediated animal movements. Red foxes were translocated from the eastern part of the continent, both intentionally for hunting and inadvertently in association with fur farming, and became established in the Willamette Valley in Oregon and the Central Valley in California during the early twentieth century (Aubry 1984; Verts and Carraway 1998; Lewis et al. 1999; Statham et al. 2012a; Sacks et al. 2016). Although primarily composed of eastern Canadian founding stock, fur farm foxes sometimes contained ancestry from Alaska or the Washington Cascades. Natural range expansions of red foxes from eastern North America, the Rocky Mountains, the Blue Mountains of northeastern Oregon, the Great Basin, and potentially western Canada, were likely facilitated in part by anthropogenic landscape changes (Fichter and Williams 1967; Green et al. 2017). These translocations and range expansions have enabled varying amounts of gene flow among populations of red foxes throughout the western U.S. (Sacks et al. 2010a, 2011, 2016; Statham et al. 2012a; Volkmann et al. 2015; Cross et al. 2018).

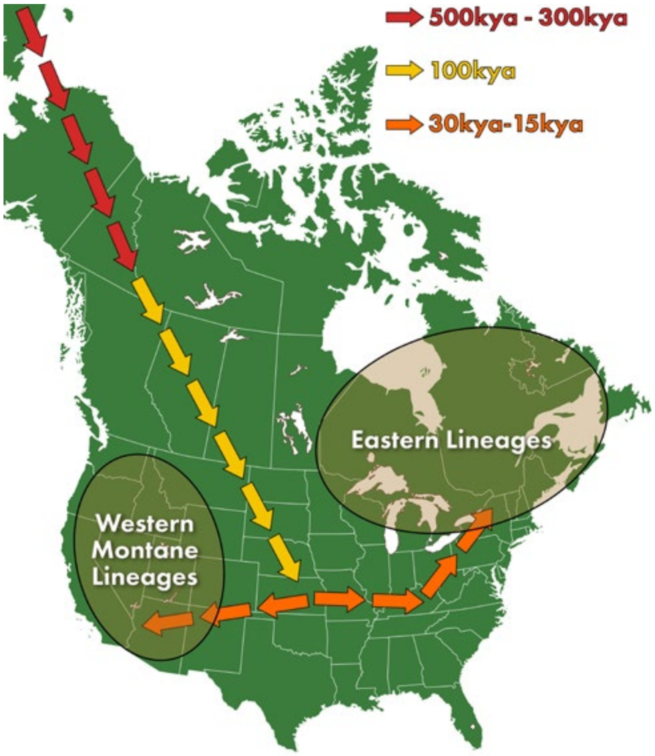

Figure 2. Evolutionary origins of red fox lineages in North America. Adapted from graphic created by Sophie Preckler-Quisquater, UC Davis.

## I.E.2. TAXONOMIC HISTORY

SNRF classification has changed over time. Baird (1857) classified all western red foxes as *V. macroura*. Merriam (1900) further distinguished montane red foxes in the Sierra Nevada as *V. necator* and in northern California, Oregon, and Washington as *V. cascadensis*. In 1929, Seton maintained that these populations represented subspecies of *V. fulva* (later revised to *V. vulpes*; Churcher 1959) rather than separate species. Grinnell et al. (1937) found no support for a subspecies distinction between red foxes in the Sierra Nevada and those in the northern California Cascades. Sacks et al. (2010a) determined via mitochondrial and microsatellite DNA analysis that montane red foxes in northern California and the Oregon Cascades were more closely related to montane red foxes in the Sierra Nevada than to montane red foxes in the Washington Cascades. Accordingly, today we recognize the SNRF range as extending from California's Sierra Nevada to the northern Oregon Cascades, with the Columbia River between Oregon and Washington forming the putative boundary between the SNRF and the Cascade red fox.

## I.E.3. WORKING DEFINITION OF THE SNRF

Throughout this Strategy, we discuss in detail the historical and contemporary genetics of populations of SNRF and other red foxes in multiple regions. To alleviate confusion, we provide the following working definition of the SNRF:

***The SNRF is 1 of 3 currently recognized subspecies of montane red fox native to North America. SNRF historically occurred in the higher elevations of the Sierra Nevada and Cascades from the Mt. Whitney region in California to the Mt. Hood region in Oregon. Populations of this subspecies currently exist in the Lassen Peak and Sierra Nevada regions of California and in the Oregon Cascades.***

***Each extant SNRF population has experienced varying levels of genetic introgression from other red fox lineages. While we recognize that these differing genetic histories may require location-specific management, we consider each of these populations to be part of the SNRF subspecies in the context of this Strategy.***

### I.E.4. POPULATIONS OF SNRF

We refer to the 3 known extant populations of SNRF as the Lassen, Sierra Nevada, and Oregon populations. Notwithstanding their contemporary genetic isolation from one another, mitochondrial DNA analysis corroborates that these populations are closely related and supports their current classification as a single subspecies of red fox (Sacks et al. 2010a).

We occasionally describe populations at a finer spatial scale if additional information warrants. Within both the Oregon and Sierra Nevada populations, SNRF have been detected in multiple distinct geographic areas that may represent isolated subpopulations or may simply result from gaps in survey coverage. Pending further surveys and genetic research to ascertain connectivity, we refer to geographically distinct SNRF detections as study areas. The Lassen population has been detected and studied since the 1990s in a single region, referred to as the Lassen study area (Figure 3). In the Sierra Nevada, we refer to the Sonora Pass, Yosemite National Park (YNP), Ritter Range, and Mono Creek study areas, where contemporary research has occurred since 2010 (Figure 4). In Oregon, where research is also ongoing since 2010, we refer to the Mt. Hood, Central Cascades, and Crater Lake National Park (CLNP) study areas (Figure 5).

### I.E.5. IMPLICATIONS OF OUR WORKING DEFINITION

Where red foxes are detected within the historical range of the SNRF but their genetic identity is unconfirmed, we conservatively presume these individuals to be SNRF, though we recognize the possibility that they could be immigrants. In some cases, individual red foxes have been identified as immigrants to SNRF populations from other subspecies or lineages, and interbreeding between immigrants and SNRF has been documented (Quinn et al. 2019; CDFW, unpublished data; UC Davis, unpublished data). Although we do not explicitly define individual immigrant foxes as SNRF if they are genetically assigned to a different subspecies, we consider these immigrants functional parts of extant SNRF populations where they breed with resident SNRF. In other cases, genetic analysis has revealed connectivity between SNRF and other subspecies, but the recency of this connectivity and the identity of interbreeding foxes is uncertain (Green et al. 2017; Quinn 2018). Our current knowledge of introgression and admixture in each SNRF population is discussed under II.D. Current Status of Known Populations and III.A.4. Potential Threats: Immigration and Introgression.

# II. BACKGROUND

## II.A. PROTECTED STATUS AND RELEVANT REGULATORY FRAMEWORKS

In California, declines in harvest and observations of SNRF led to a ban on trapping red foxes in 1974 and the subspecies' listing as threatened under the California Endangered Species Act (CESA) in 1980. Possession, purchase, and take of SNRF in California are prohibited under CESA without a permit from CDFW.

In Oregon, all wild red foxes are classified as furbearers, and all forms of take and associated penalties are defined in state statutes and rules (Oregon Administrative Rules 635-050 and Oregon Revised Statutes Chapters 496 and 498). In 2016, the SNRF was added to ODFW's Oregon Conservation Strategy as a "sensitive species" in the East Cascades, West Cascades, and Klamath Mountains ecoregions due to a

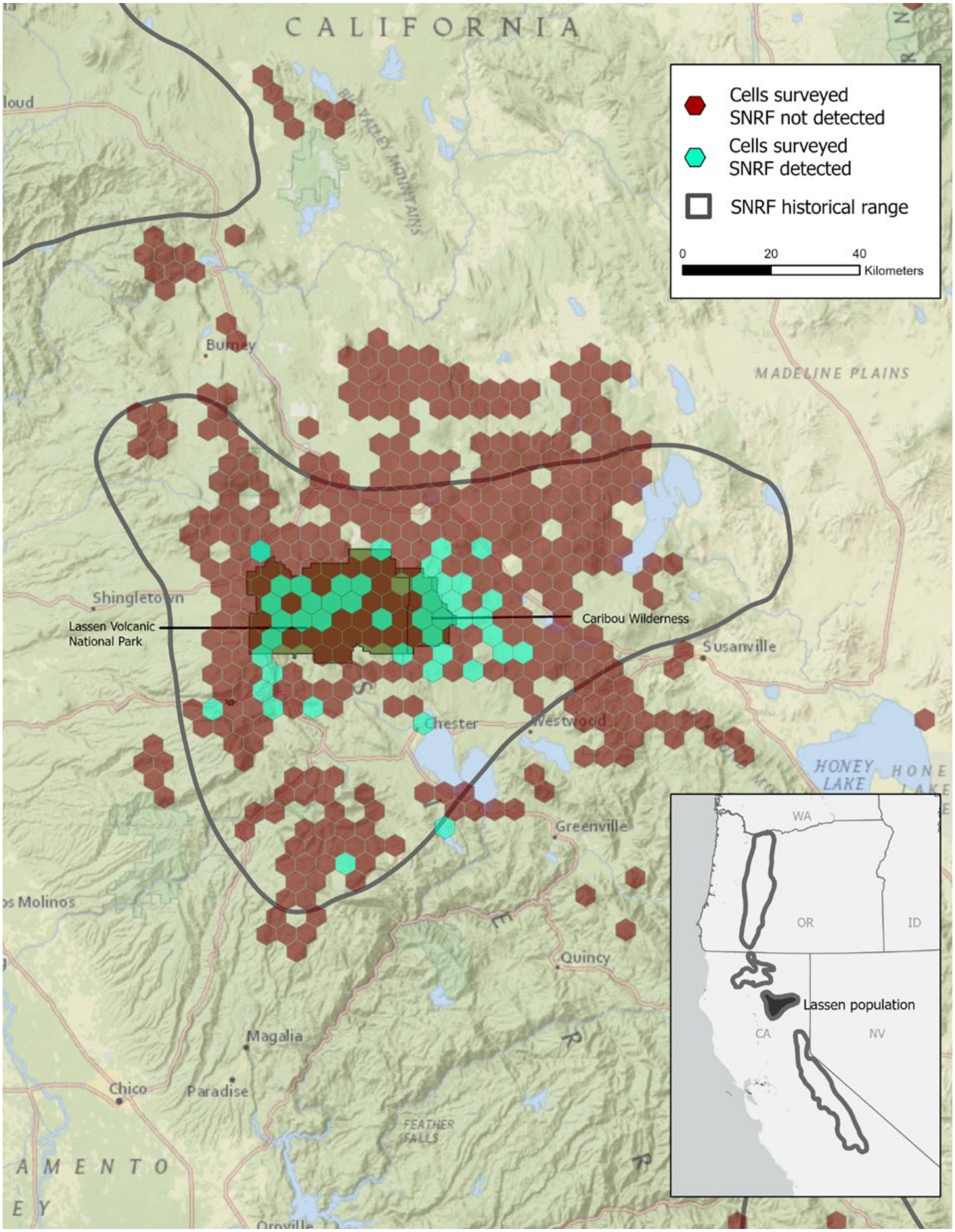

Figure 3. Estimated historical distribution, contemporary remote camera and scat survey efforts, and SNRF detections in the Lassen study area from 1992–2020. SNRF locations from telemetry and GPS collars are not included.

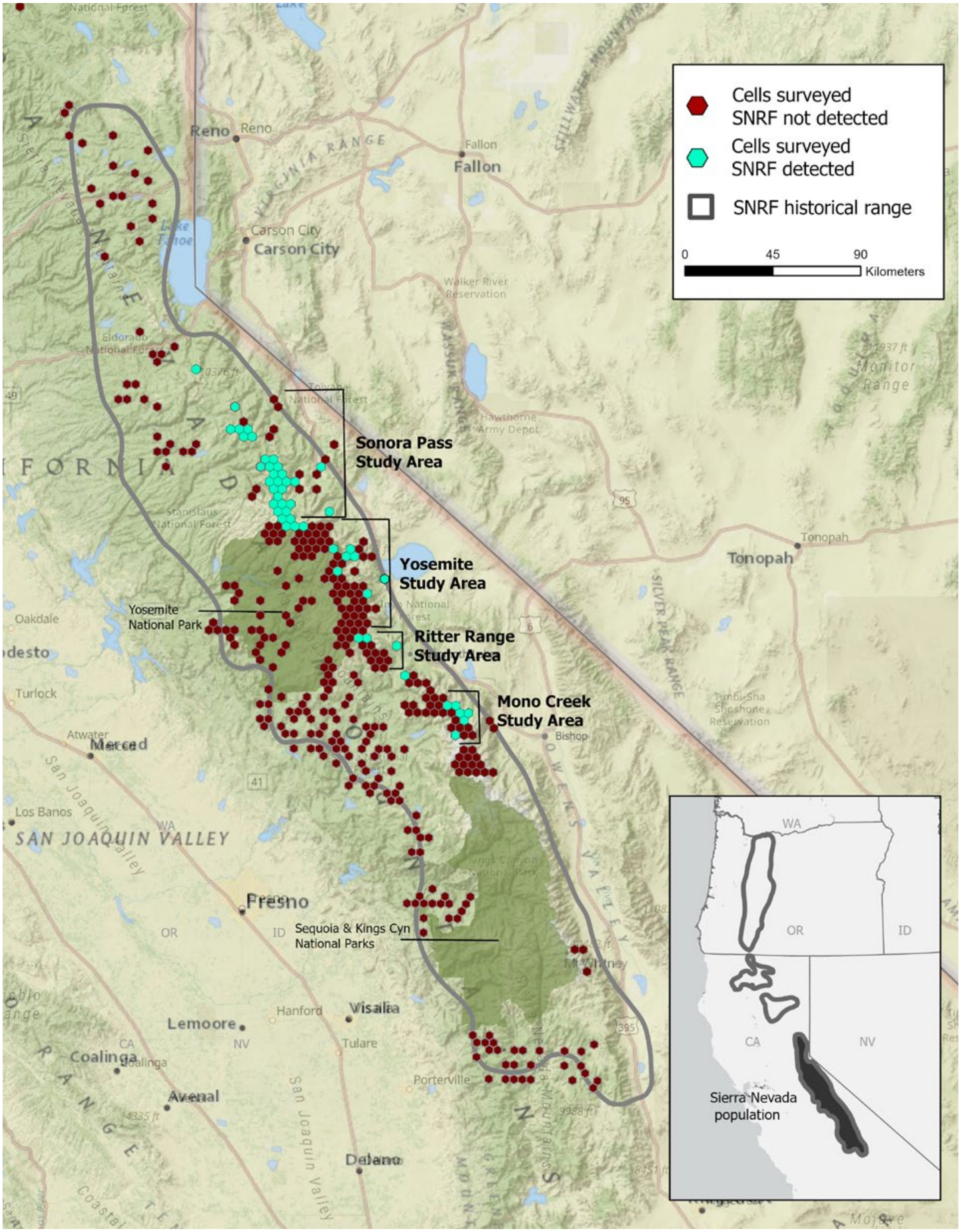

Figure 4. Estimated historical distribution, contemporary remote camera and scat survey efforts, and SNRF detections in the 4 study areas in the Sierra Nevada from 2010–2020.

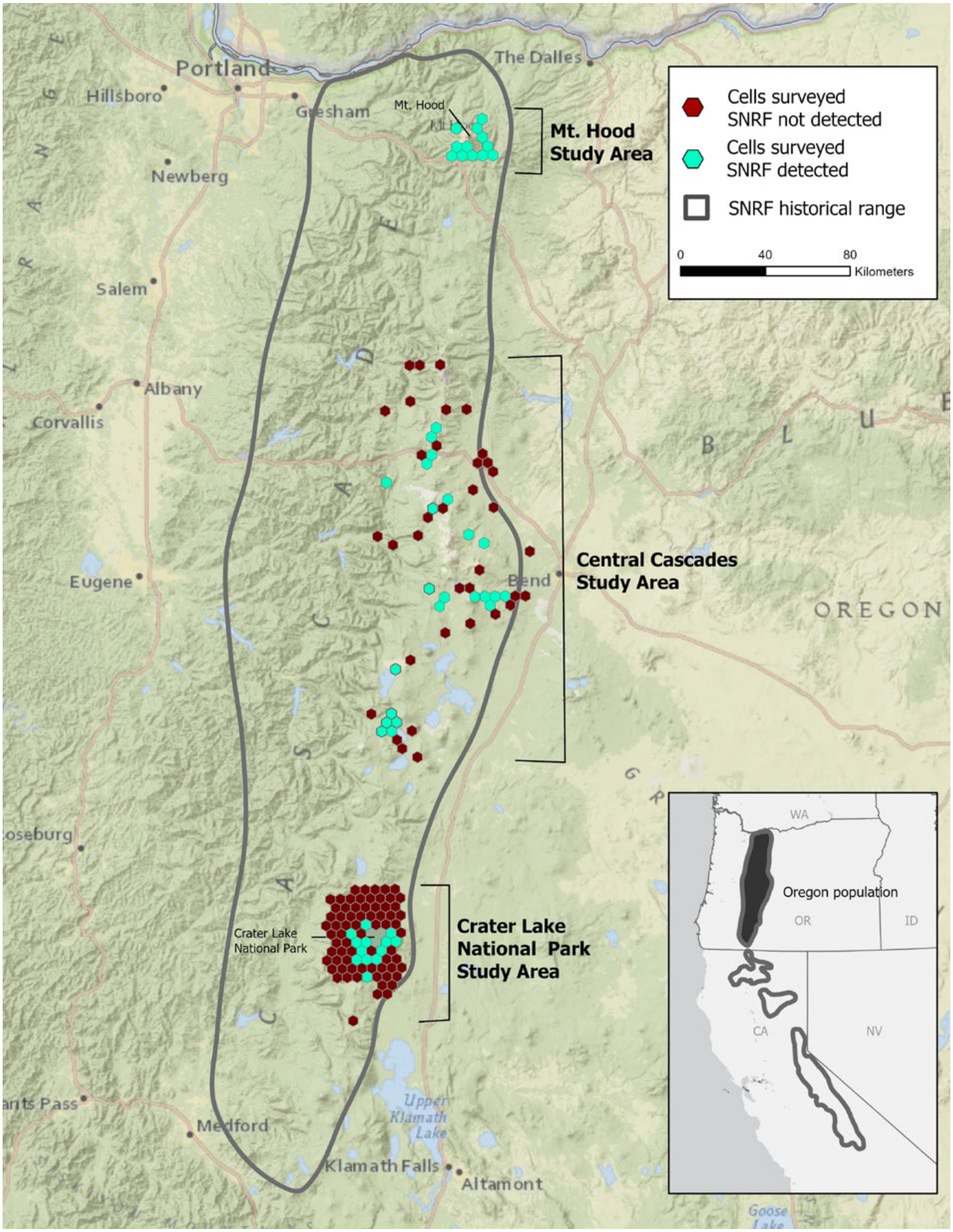

Figure 5. Estimated historical distribution, contemporary remote camera and scat survey efforts, and SNRF detections in the 3 study areas in Oregon from 2010–2020. SNRF locations from telemetry and GPS collars are not included.

lack of information about population status and trend (ODFW 2016). This designation prioritizes research on the subspecies, but does not confer any specific protections beyond those of the furbearer classification.

The SNRF is classified as a "sensitive species" by USFS in the Pacific Southwest Region (1998), on the Humboldt-Toiyabe National Forest (2011), and throughout its range in the Pacific Northwest Region (2019). Accordingly, land use and management in USFS-administered SNRF habitat must be planned and implemented so as to maintain SNRF population viability. In the Sierra Nevada region in California, the *Sierra Nevada Forest Plan Amendment Standards and Guidelines* (USFS 2004) stipulate that any actions conducted within an 8-km radius of a verified SNRF detection must be analyzed for potential impacts to the subspecies.

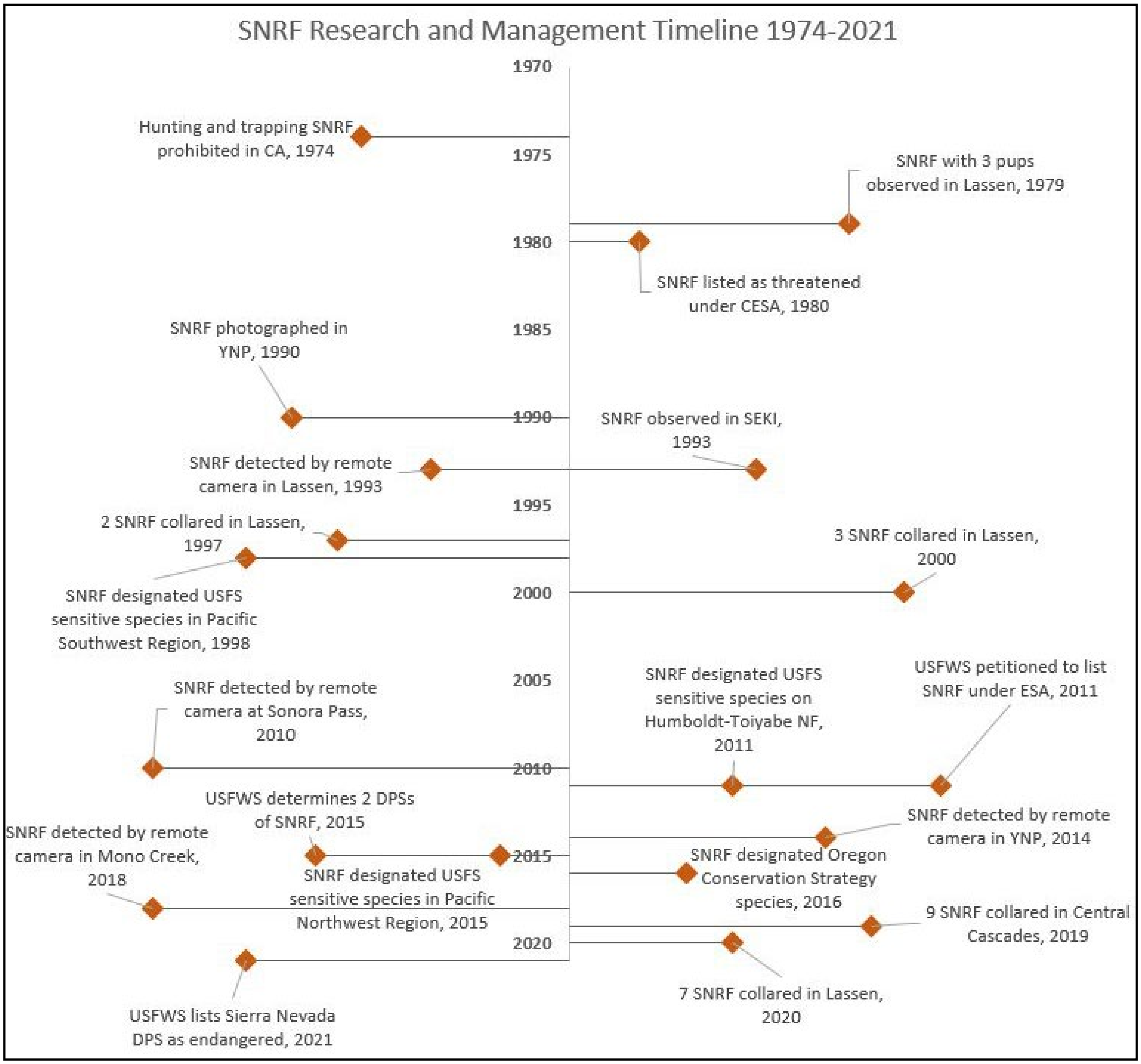

Figure 6. Timeline of milestones in research and management of the SNRF, 1974-2021.

In 2015, USFWS recognized 2 DPSs of the SNRF: the Southern Cascades DPS (encompassing the Oregon and Lassen populations) and the Sierra Nevada DPS (comprising the historical range within the Sierra Nevada; USFWS 2015a). The Sierra Nevada DPS was found to warrant listing under ESA, whereas the Southern Cascades DPS was not found to warrant listing. In August 2021, USFWS published a rule listing the Sierra Nevada DPS of the SNRF as endangered under ESA (Figure 6; USFWS 2021). A federal recovery effort will be initiated to complement existing conservation planning and to build upon the recommendations in this Strategy.

## II.B. SNRF BIOLOGY UPDATE

For a detailed overview of red fox biology and ecology, we refer readers to the Sierra Nevada Red Fox Conservation Assessment (Perrine et al. 2010) and Species Status Assessments (SSA; USFWS 2015b, 2018). Here, we briefly summarize relevant biological information and report recent findings. Although the basic natural history of the SNRF has been established by a small number of field studies, specific information is lacking for several important aspects of SNRF biology, including demographics, vital rates, population dynamics, fine-scale habitat selection, and community ecology; we elaborate on these knowledge gaps in section III.B. Information Needs.

### II.B.1. MORPHOLOGY

SNRF are small, slender canids with long snouts and large ears. The pelage of SNRF varies from reddish-orange to black, with an intermediate color morph characterized by grayish-blonde pelage and darker hairs that form a cross shape down the back and along the shoulders (Bailey 1936; Grinnell et al. 1937; Perrine et al. 2010). The key features that distinguish SNRF from coyotes and gray foxes are bushy, white-tipped tails nearly the length of their bodies, black on the backs of their ears, black feet, and (often) black legs (Grinnell et al. 1937; Statham et al. 2012b). Coyotes and gray foxes have rust-colored ears and forelegs. Coyotes have proportionally shorter, thinner tails that typically have black tips; gray foxes have long tails that are thinner and flatter in cross-section, with a black dorsal stripe and black tip.

Figure 7. A red-pelage SNRF photographed by remote camera at approximately 3,000 m elevation in the YNP study area in December 2014. Photo courtesy of NPS.

SNRF display several physical traits that may be adaptations to the cold, snowy, low-productivity mountain environment (Figure 7). SNRF have slightly smaller bodies and a greater foot-surface-to-body-mass ratio compared to lowland red foxes, presumably to facilitate travel on deep snow. SNRF also have thick coats and small foot pads

Figure 8. Comparison of hair growth on toe pads of a Sacramento Valley red fox (left) and a SNRF (right) killed by vehicle strikes in January 2011. Photos courtesy of Mark Statham (left) and Mourad Gabriel (right).

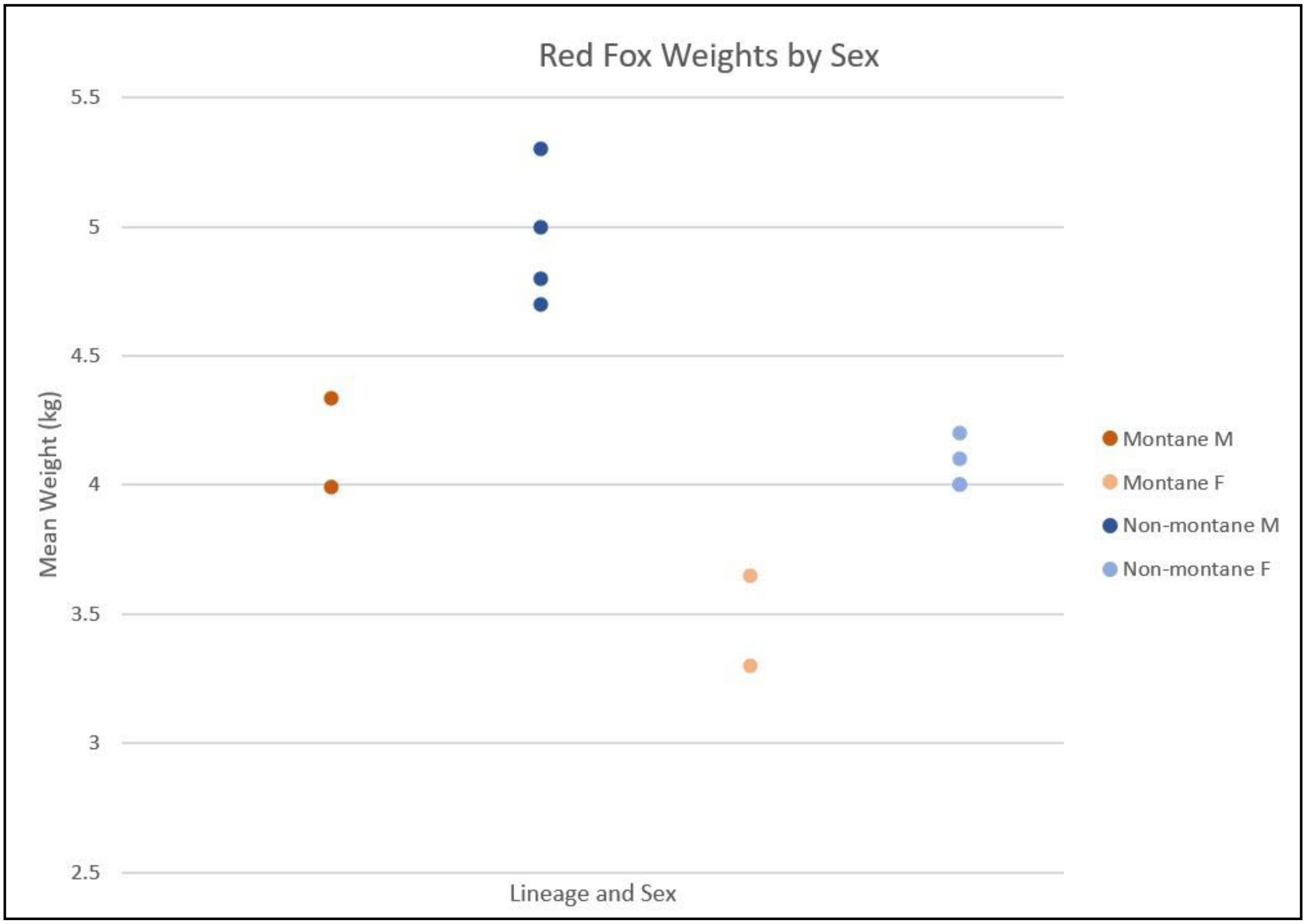

Figure 9. Comparison of mean weight by sex for montane and non-montane red foxes in North America (Bailey 1936; Grinnell et al. 1937; Hoffman and Kirkpatrick 1954; Storm et al. 1976; Aubry 1983; Perrine 2005; Sacks et al. 2010b; CDFW, unpublished data; ODFW, unpublished data, C. Quinn, UC Davis, unpublished data).

covered in dense hair during winter, which provide protection and insulation from cold and snow (Figure 8). Weights of red foxes vary widely (Figure 9). Mean weights reported for adults in lowland North America range from 4.7 to 5.3 kg for males and from 4.0 to 4.2 kg for females (Hoffman and Kirkpatrick 1954; Storm et al. 1976; Roest 1977; Sacks et al. 2010b). The mean weights of SNRF captured in California and Oregon during 1998–2019 were 4.0 kg for males (n = 5) and 3.7 kg for females (n = 17).

## II.B.2. REPRODUCTION

### II.B.2.1. BEHAVIOR AND PHENOLOGY

Limited observations of breeding pairs of SNRF suggest that, like other red fox subspecies, they are monogamous (Grinnell et al. 1937; Verts and Carraway 1998; Quinn et al. 2019; CDFW, unpublished data). Based on observations of pups and pregnant females, SNRF females likely experience estrus in February or March, with birth occurring in April or early May (Figure 10; C. Quinn, UC Davis, unpublished data; CDFW,

Figure 10. SNRF pup photographed by remote camera in the Lassen population in July 2018. Photo courtesy of CDFW.

unpublished data; ODFW, unpublished data). Observations of the Cascade red fox, a closely related montane subspecies with presumably similar biology, suggest estrus in February to early March and birth as late as mid-April (J. Akins, Cascades Carnivore Project, unpublished data). By contrast, the average parturition date for Sacramento Valley and lowland red foxes in California is March 1 (Sacks et al. 2010b), 1–2 months earlier than that of montane red foxes at the same latitudes. Later reproductive phenology in montane versus lowland red foxes may be an adaptation to later snowmelt and spring vegetation growth at higher elevations, and has been hypothesized to limit matrilineal gene flow from lowland red foxes into montane red fox populations (Cross et al. 2018). The timing of estrus is thought to be similar for foxes at similar latitudes (Lloyd 1980; Cavallini and Santini 1995), suggesting that there may be a genetic basis for the difference in reproductive phenology between lowland and montane red foxes at similar latitudes in California.

Locations and attributes of SNRF dens are discussed below in section II.C.4. Den-site Selection.

### II.B.2.2. LITTER SIZE

Litter sizes reported in contemporary research for SNRF and other montane subspecies are notably smaller than those of lowland red foxes (Figure 11). Although trappers interviewed by Grinnell et al. (1937) reported that SNRF litters ranged up to 9 pups, we are aware of no documented litter size of more than 4 offspring for any montane subspecies. In the Lassen population, a litter of 3 pups was documented in 1979, a litter of 2 in 1999, a litter of 1 in 2018, and a litter of 3 in 2019. In the Sonora Pass study area, the largest litter detected from a single pair of adults in a given year was 4 pups; most litters contained 1–3 pups (Quinn et al. 2019). In the Central Cascades study area, ODFW observed a litter of 3 pups and a litter of 2 pups in 2018, and a litter of 2 pups in 2019 (ODFW, unpublished data)[2].

The apparently relatively small litter sizes of montane red foxes contrast with an average litter size of 4 to 6 in lowland red fox populations throughout North America (e.g., midwestern red foxes, Storm et al. 1976; Lloyd 1980; Sacramento Valley and admixed California lowland red foxes, Sacks et al. 2010b). It is unknown what specific reproductive process (e.g., ovulation, in-utero failure of implanted embryos, neonatal mortality) drives small litter sizes. Further, it is unclear the extent to which litter size is environmentally as opposed to genetically determined. However, small litter size in montane subspecies is consistent with expectations for local adaptations to lower resource availability and colder temperatures in the subalpine zone. Life-history theory predicts that litter size should be optimized according to a trade-off between current reproductive success (annual pup production/survival) and future reproductive success (annual productivity), both of which are linked to resource availability and other energetic pressures such as thermogenesis (Stearns 1980). In a low-resource

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[2] These litter size estimates are based on juveniles detected post-partum and are therefore minimum estimates.

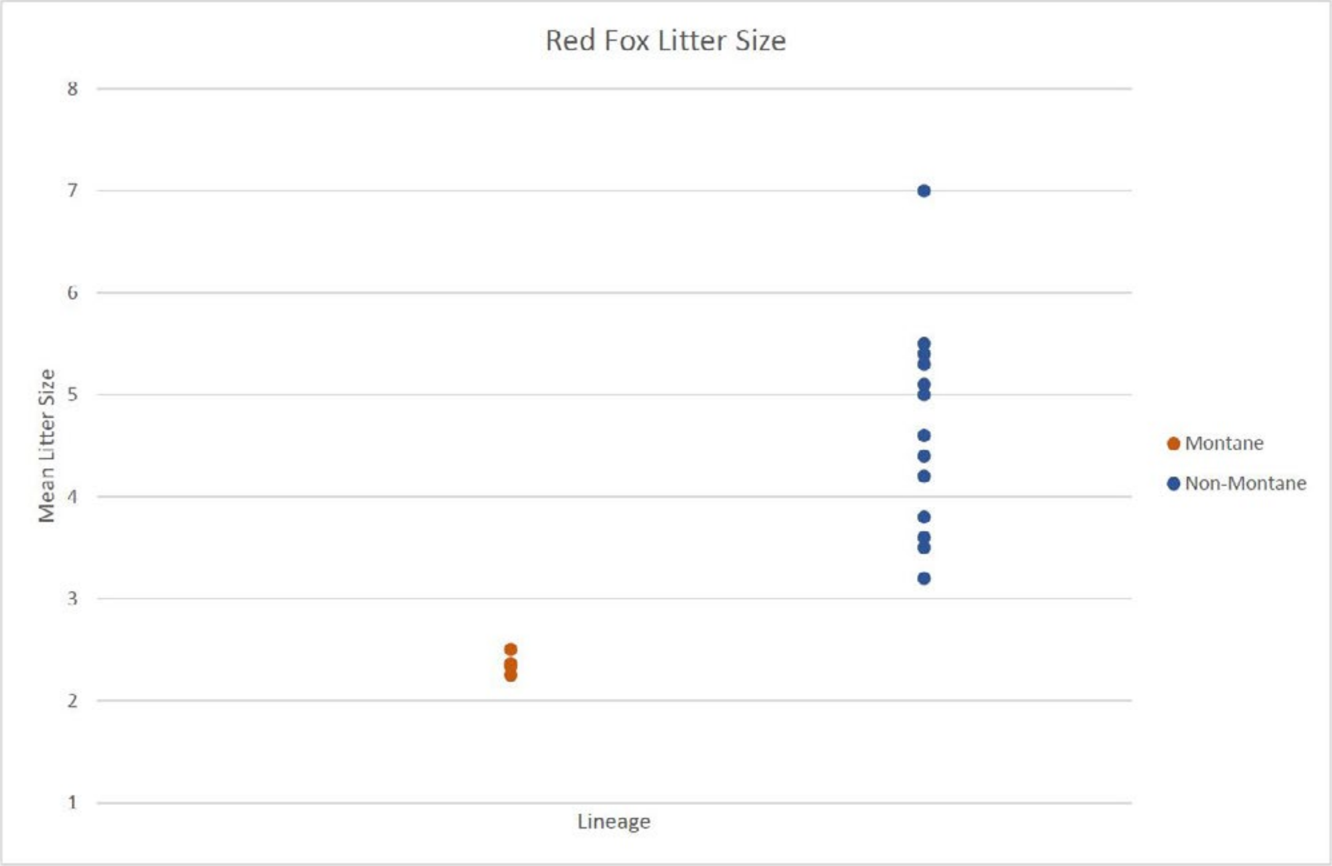

Figure 11. Mean litter sizes of montane and non-montane red foxes in North America (Grinnell et al. 1937; Storm et al. 1976; Aubry 1983; Perrine et al. 2010; Sacks et al. 2010b; Quinn et al. 2019; CDFW, unpublished data; ODFW, unpublished data).

environment, fewer pups can be adequately provisioned without overtaxing the energetic capacity, health, and future reproductive success of parents, thereby applying a selective pressure against parents with larger litters (Sacks and Neale 2001).

## II.B.3. MORTALITY

Contemporary research has confirmed the cause of death for only 11 SNRF: 1 in the Lassen population from predation by a domestic dog, 2 in the Central Cascades study area from potential predation (1 suspected coyote predation and 1 suspected bobcat predation), 1 in the Central Cascades study area from trapper by-catch, and 7 from vehicle strikes (1 in the Sonora Pass study area, 1 in the CLNP study area, and 5 (3 juveniles, 1 adult, and 1 individual of unknown age) in the Central Cascades study area (Perrine 2005; Statham et al. 2012b; CDFW, unpublished data, ODFW, unpublished data, NPS, unpublished data). One red fox found within historical SNRF habitat in the Central Cascades study area in 2019 may have died from rodenticide via secondary poisoning, but definitive determination of the cause of death was not possible (J. Burco, ODFW, and D. Clifford, CDFW, personal communications 2020).

Numerous potential causes of mortality are enumerated in section III.A. Potential Threats, but evidence suggests adult mortality may not be limiting SNRF. During 2010–2015, Quinn et al. (2019) estimated average minimum annual survival of SNRF in the Sonora Pass study area at 0.70 and minimum first-year survival at 0.59, higher than the survival rates of 0.40–0.55 reported by studies of low-elevation red fox populations (Lloyd

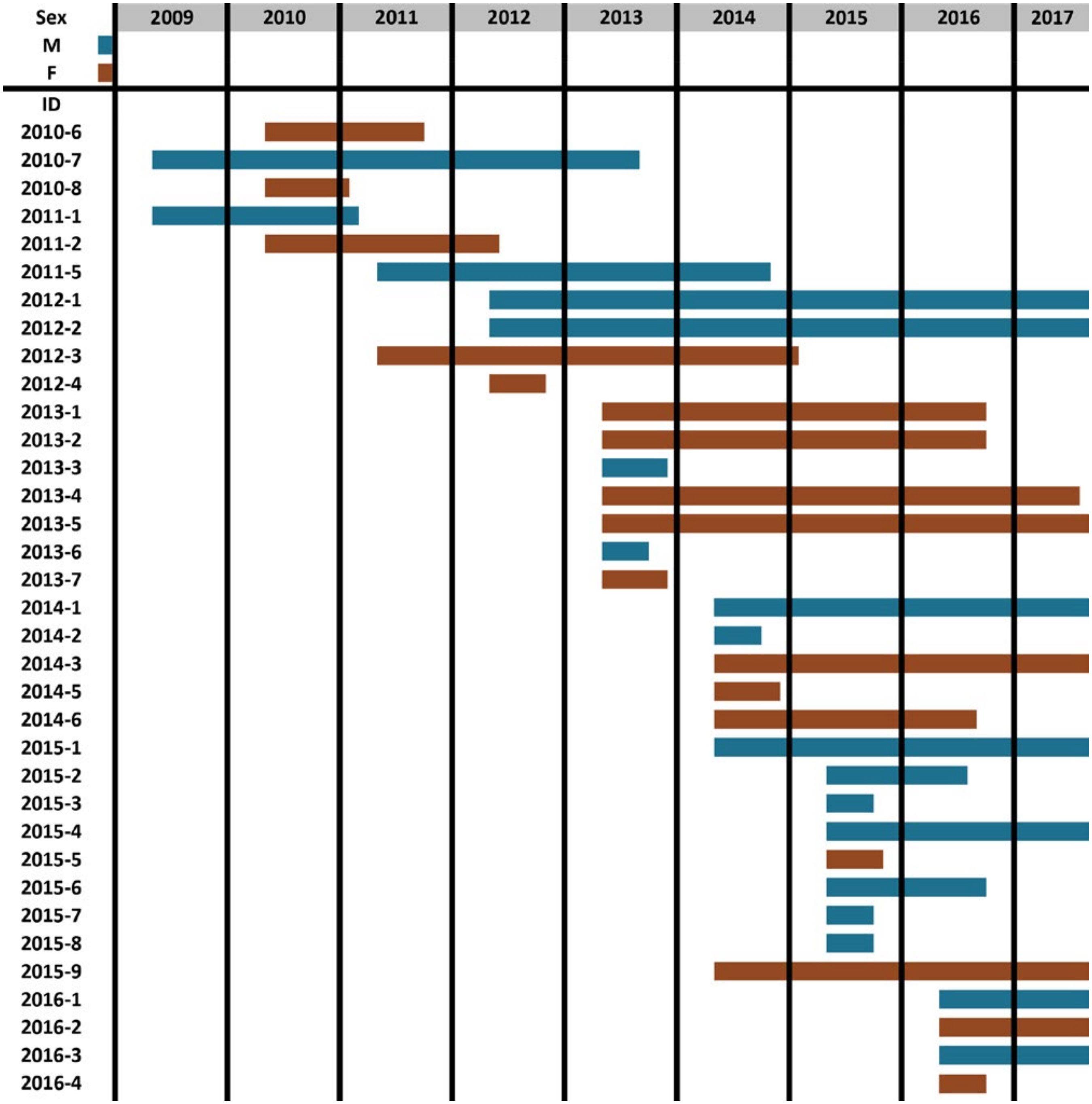

Figure 12. Minimum lifespan (based on scat samples) of individuals in the Sonora Pass study area during 2009-2017. Adapted from Figure 5 in Quinn et al. 2019.

1980; Gosselink et al. 2007; Converse 2012; Devenish-Nelson et al. 2013). Additionally, long-term monitoring in the Lassen and Sonora Pass study areas indicates adults have relatively long lifespans. Numerous individuals detected in the Sonora Pass study area lived for more than 4 years (Figure 12), and out of 28 individuals detected at Lassen during 2007–2018, 1 lived for at least 7 years, 2 for at least 6.5 years, and 3 for at least 5.5 years (Figure 13). Storm et al. (1976) reported that few red foxes lived past 6 years, but their study may not be comparable, as it took place in a midwestern

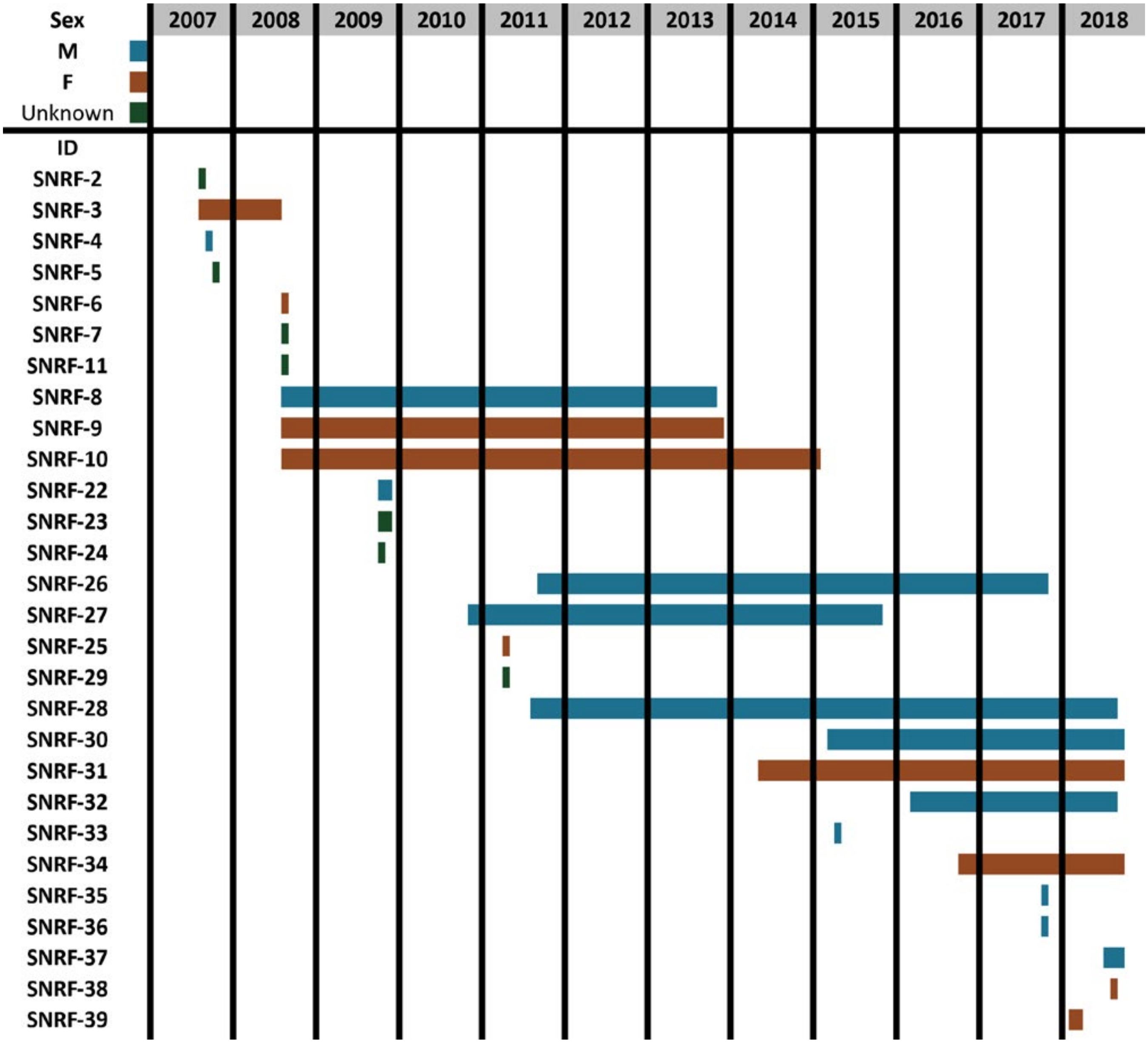

Figure 13. Minimum lifespan (based on scat samples) of individuals in the Lassen population during 2007-2018 (CDFW, unpublished data).

population that experienced relatively high levels of harvest.

Along with low fecundity, juvenile and neonatal mortality may have greater consequences for population growth in SNRF than adult mortality. At this time, aside from 3 juvenile SNRF killed in separate instances by vehicle strikes in the Central Cascades study area, we have little information on rates or causes of juvenile mortality in SNRF.

## II.B.4. DIET

Most of what we know about SNRF diet comes from data collected during summer and fall, when the highest diversity of prey items and vegetative food is available. During this time, SNRF have a relatively broad diet, primarily composed of small mammals (Figure 14). We have far fewer data on winter and spring diets when food resources are scarce and the energetically expensive processes of ovulation,

Figure 14. SNRF with small rodent prey in CLNP, 2007. Photo courtesy of Ron Larson and Sean Mohren.

gestation, and lactation occur. Winter diet may be more directly linked to population growth than summer diet.

To assess the seasonal diet of SNRF in the Lassen study area, Perrine (2005) analyzed the contents of 227 putative red fox scats collected primarily in the western half of Lassen Volcanic National Park (LVNP) and the adjacent Lassen National Forest. Most scats were collected during the summer and fall. He found the diet to be composed primarily of mammals, especially rodents, and supplemented by birds and insects. Manzanita berries were commonly consumed in the fall, and mule deer (presumably as carrion) were a major component of diet in the winter and spring. Leporids were virtually absent from the diet.

CDFW and UC Davis (unpublished data) analyzed 148 genetically confirmed SNRF scats collected during 2008–2015 in the Lassen study area, the majority of which were from summer months. Most of the scats were collected in or near the Caribou Wilderness east of LVNP. The findings were similar to those of Perrine (2005). Rodents (including pocket gophers, squirrels, voles, and mice), deer, insectivores (shrews, moles), and birds were prevalent food items. Arthropods and manzanita berries were common. However, in contrast to Perrine's (2005) findings, leporid remains were found in 15% of total scats and were more frequent (44%) in scats collected during winter and spring, although the sample size for winter and spring scats was small (n = 27). The difference in leporid prey occurrence between the 2 studies may reflect spatial or temporal variation in local snowshoe hare abundance. Prey remains and remote camera photos from dens used by SNRF in 2019 also suggested a diverse diet in summer and early fall, including yellow-bellied marmots, snowshoe hares, martens, deer (carrion), deer mice, and voles.

Poisson et al. (2019) performed diet analysis through DNA metabarcoding of SNRF scats collected in Oregon during summers 2015–2018. They found a diverse diet comprising 19 species of mammals, birds, and fishes. Deer mice were the prey species identified most commonly in the scats. Deer, elk, golden-mantled ground squirrels, snowshoe hares, Trowbridge's shrews, western red-backed voles, and yellow-pine chipmunks also occurred frequently in scats.

In the Sierra Nevada, whitebark pine nuts are commonly found in SNRF scats collected in the fall (CDFW, unpublished data; C. Quinn, UC Davis, unpublished data). The relative importance of this food source for SNRF in the Sierra Nevada population is not known. However, in a study of Rocky Mountain red foxes, a closely related montane subspecies in Yellowstone National Park, Wyoming, Cross (2015) found that whitebark pine nuts were a variable but occasionally substantial component of scats. During the winter of 2013, whitebark pine nuts were present in 14 of 30 scats collected and comprised an average of 61% of the contents of scats in which they occurred. A lack of whitebark pine nuts in scats collected the following winter coincided with "generally poor cone production" in the region (Haroldson 2013:1), suggesting that montane red foxes may consume whitebark pine nuts in proportion to their availability (Cross 2015).

Informal efforts by USFS and CDFW to spatially track the fate of large food items have provided evidence that SNRF sometimes cache food. In late May 2015, VHF transmitters were attached to a chicken carcass and to a sooty grouse carcass in the Lassen National Forest, and both were left in an area where a SNRF had been detected recently. A remote camera photographed a SNRF moving each food item. The items were later found in separate locations over 0.6 km away from where they were initially placed. Each had been buried. Remote cameras were then set up to monitor the cached items. A coyote dug up the chicken carcass 3 to 4 days after it was buried, and there was no indication the fox returned to the site within the monitoring period. The fox also did not return to the grouse caching site within the monitoring period.

SNRF inhabit a low-productivity environment, especially throughout the breeding season when energy requirements are highest for pregnant or nursing females. Large-bodied prey, especially leporids that do not hibernate, may provide SNRF with a vital caloric resource during this time period. This is supported to some extent by field studies showing higher snowshoe hare occurrence in scats during winter, as in Cross's (2015) study of Rocky Mountain red foxes in Montana, where 45% of winter scats contained snowshoe hares, while summer scats contained a more even distribution of prey types. A similar seasonal pattern of snowshoe hare occurrence in scats was observed in the Lassen study area (CDFW, unpublished data; C. Quinn, UC Davis, unpublished data).

Despite their varied diet, a hypothesis in need of further investigation is that SNRF reproduction (and possibly survival) is sensitive to the availability of leporid prey in late winter and early spring. If so, population dynamics of both leporids and SNRF could be naturally linked and variable across years.

## II.B.5. BEHAVIOR TOWARD HUMANS

Worldwide, red foxes are known for their successful adaptation to urban, suburban, and agricultural environments (Harris and Smith 1987; Kurki et al. 1998; Wandeler et al. 2003; Luniak 2004). However, Grinnell et al. (1937:386) noted the SNRF's elusiveness, remarking that the subspecies "is rarely found in well-settled country or even anywhere near cultivated lands."

Most recent observations of SNRF behavior are limited to remote camera photos or videos, live-captures, and opportunistic encounters near developed or heavily used recreation sites. These limited and anecdotal data constrain our inferences about SNRF behavior toward humans. However, anecdotal data suggest substantial individual behavioral variation in SNRF and other montane red foxes. Some foxes may be averse to human presence or manmade structures, even avoiding camera stations in remote wilderness areas (Poisson et al. 2019; J. Akins, Cascades Carnivore Project, unpublished data). Even foxes that inhabit human-

Figure 15. A collared SNRF begging for food at a campground in LVNP. Photo courtesy of John Perrine, August 1998.

dominated environments may avoid humans; GPS collar data from the Lassen population revealed that SNRF visited a popular day use recreation area mainly at night, perhaps to scavenge food and trash without encountering humans (CDFW, unpublished data). Other foxes become habituated to humans, begging for food or trash, or denning and foraging near ski resorts, parking lots, campgrounds, and active roadways (Figure 15; Perrine 2005; Jenkins et al. 2014; T. Hiller, Wildlife Ecology Institute, personal communication 2019; CDFW, unpublished data; NPS, unpublished data; ODFW, unpublished data; C. Quinn, UC Davis, unpublished data; USFS, unpublished data).

Remote camera and telemetry data indicate that SNRF are typically more active between dusk and dawn than during daylight hours (Perrine 2005; CDFW, unpublished data), though daytime foraging may be more common in winter and spring when reproduction and pup-rearing occur (Ables 1975; Voigt 1987). Habituated SNRF may alter their activity patterns to correspond to the timing of greatest human presence or presence of anthropogenic food or trash. For example, habituated SNRF in the Central Cascades study area in Oregon have been observed to shift their use from ski resorts in winter to nearby campgrounds in late spring, apparently following the greatest concentration of humans (ODFW, unpublished data).

Section III.A.7. Potential Threats: Recreation, Habituation, and Development provides an overview of potential negative effects of human presence on SNRF and other carnivores.

# II.C. DISTRIBUTION, HABITAT, AND SPACE USE

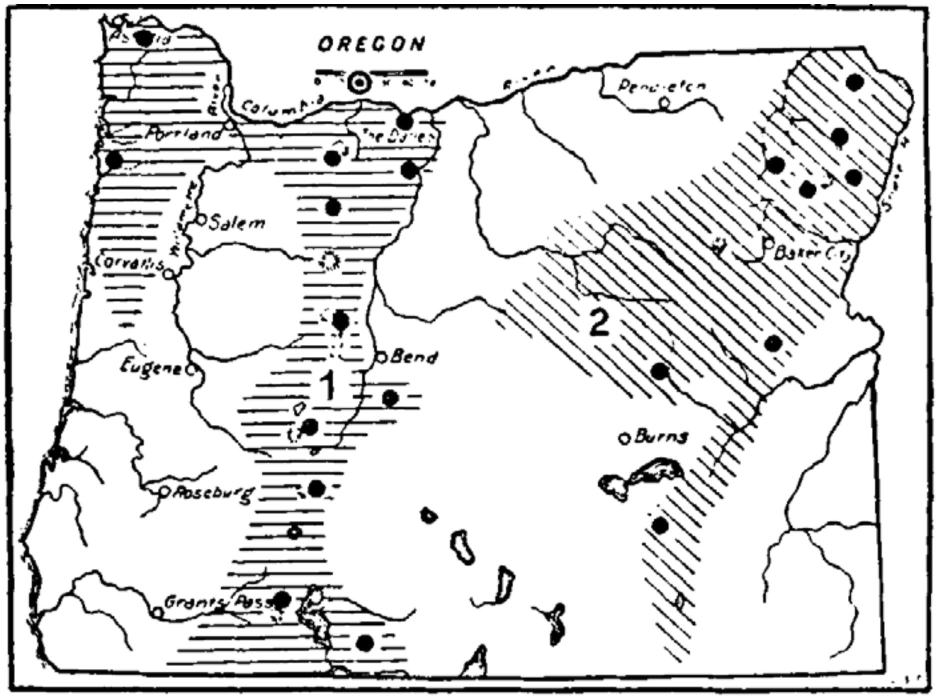

Figure 16. Estimated historical distribution of SNRF (formerly *V. v. cascadensis*) and other red fox subspecies in Oregon (Bailey 1936).

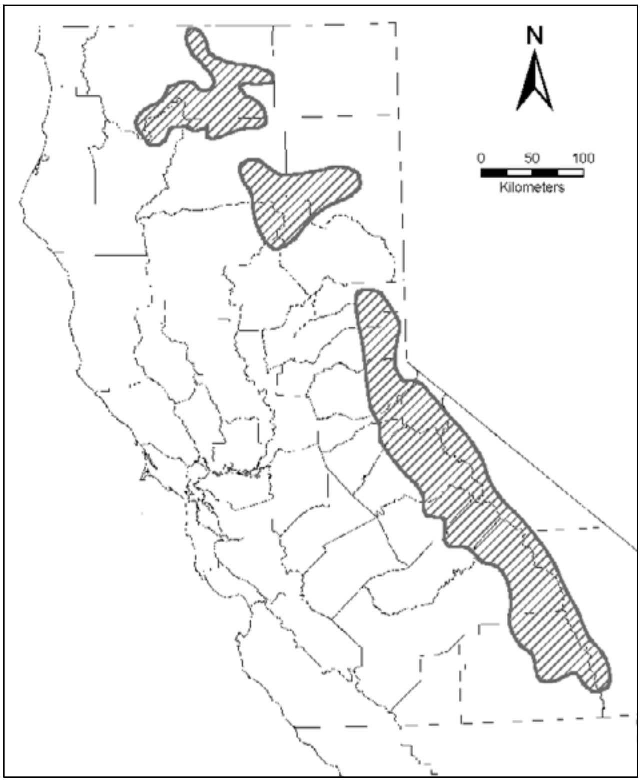

Figure 17. Estimated historical distribution of SNRF in California (Perrine et al. 2010, adapted from Grinnell et al. 1937).

# II.C.1. DISTRIBUTION

## II.C.1.1. HISTORICAL RANGE-WIDE DISTRIBUTION

According to historical records, as recently as a century ago SNRF were distributed throughout the montane, subalpine, and alpine zones of the Sierra Nevada, Klamath Mountains, and Cascades in California and Oregon (Figure 16; Bailey 1936; Figure 17; Grinnell et al. 1937). In the Sierra Nevada, Grinnell et al. (1937) reported that the typical elevation of detections was above 2,130 m, although observations were recorded as low as 1,370 m. In the Lassen and Shasta regions, Shempf and White (1977) summarized historical detection records and determined that the elevation of detections ranged from 1,646 m to 2,256 m with a mean elevation of 1,951 m. The "higher elevations" of the Oregon Cascades historically occupied by SNRF are not delineated in the literature, but may have included elevations as low as 1,220 m (USFWS 2018).

## II.C.1.2. CURRENT DISTRIBUTION

Figure 1 shows the distribution of remote camera and scat survey efforts and SNRF detections since the earliest contemporary studies began in 1998. At the coarsest scale, the minimum current range of the SNRF comprises 3 broad geographic areas: LVNP and the surrounding Lassen National Forest, the Sierra Nevada between Highway 88 and the Mono Creek watershed, and the crest of the Oregon Cascades between Mt. Hood and CLNP. Surveys and detections are reported at the scale of the 10.4-km2 hexagonal cells used by multiple agencies to design and implement carnivore occupancy surveys.

While surveys can help to confirm the presence of SNRF, it is important to note that the lack of detections in a surveyed cell does not necessarily indicate absence of SNRF. Additionally, areas of the historical range where SNRF surveys have not been conducted should be interpreted conservatively as gaps in knowledge, rather than true gaps in distribution.

Multiple independent researchers have modeled the current distribution of SNRF in California and Oregon. These models provide resource managers with tools to aid in the conservation of SNRF by prioritizing regions requiring additional surveys and research. Cleve et al. (2011) produced 3 models comparing presence-absence and presence-only methods based on occurrence data from the Lassen study area, which at the time of model development was the only region known to be occupied by SNRF (Figure 18). The best-performing model indicated high habitat suitability throughout the historical range of SNRF in California, and found that satellite image greenness and low winter minimum temperatures were the best predictor variables for SNRF presence. This model identified suitable habitat within the Sonora Pass study area, where SNRF were detected in 2010, and provided a basis

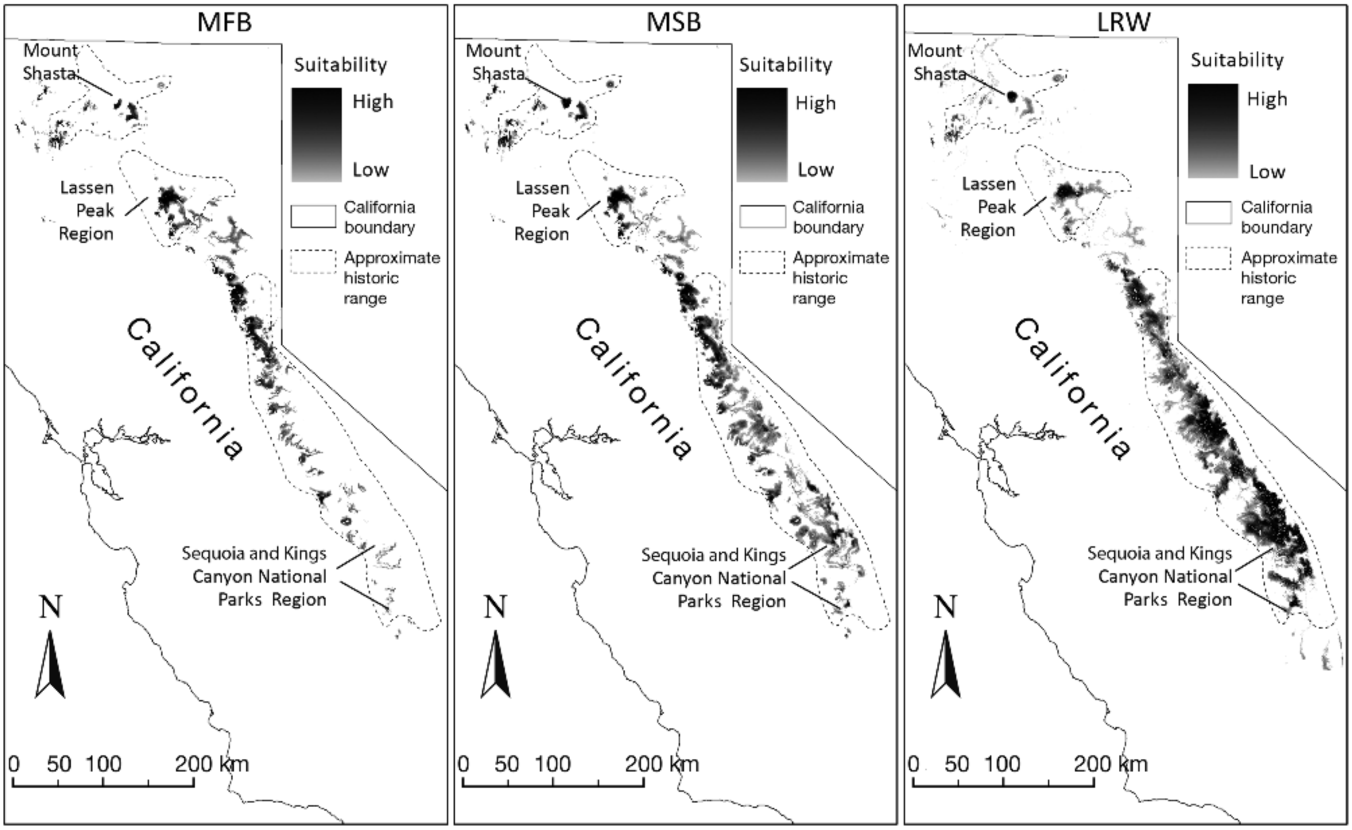

Figure 18. Predicted suitable habitat for SNRF based on 3 models: Maxent full background pixels (MFB), Maxent with subsetted background pixels (MSB), and spatially-weighted logistic regression (LRW). The dashed line represents the historical range (Grinnell et al. 1937). From Figure 2 in Cleve et al. 2011.

for the design of subsequent surveys in the Sierra Nevada.

Based on Cleve at al.'s (2011) distribution models, Spencer and Rustigian-Romsos (2012) modeled core habitat areas and movement corridors for the SNRF in California. This model indicated that there is low potential for connectivity between habitat cores in the Lassen Peak and Sierra Nevada regions. The model identified shorter distances and fewer barriers between habitat cores in the Sierra Nevada, suggesting that there is higher potential for connectivity within this region.

Quinn et al. (2018) modeled potential SNRF distribution in the Oregon Cascades using a presence-only method (Figure 19). The predicted distribution was nearly continuous along the Cascades crest except for a gap between Mt. Hood and Mt. Jefferson, implying high potential for connectivity between study areas in Oregon. The strongest predictors of SNRF presence were intermediate minimum January temperatures (between -7.5 and -4.5° C) and land-cover type including alpine habitats, subalpine forests, montane meadows, silver fir/mountain hemlock forests, and lava. Ponderosa pine forests had a substantial negative influence on probabilities of SNRF occurrence.

Akins (2017) developed occupancy-based and presence-only distribution models for the Cascade red fox, a closely related montane subspecies in Washington with very similar ecological characteristics. Probability of occurrence was greatest at elevations from 1,500 m to 2,700 m, on moderate slopes (approximately 15°), in areas with low maximum annual temperatures, high winter

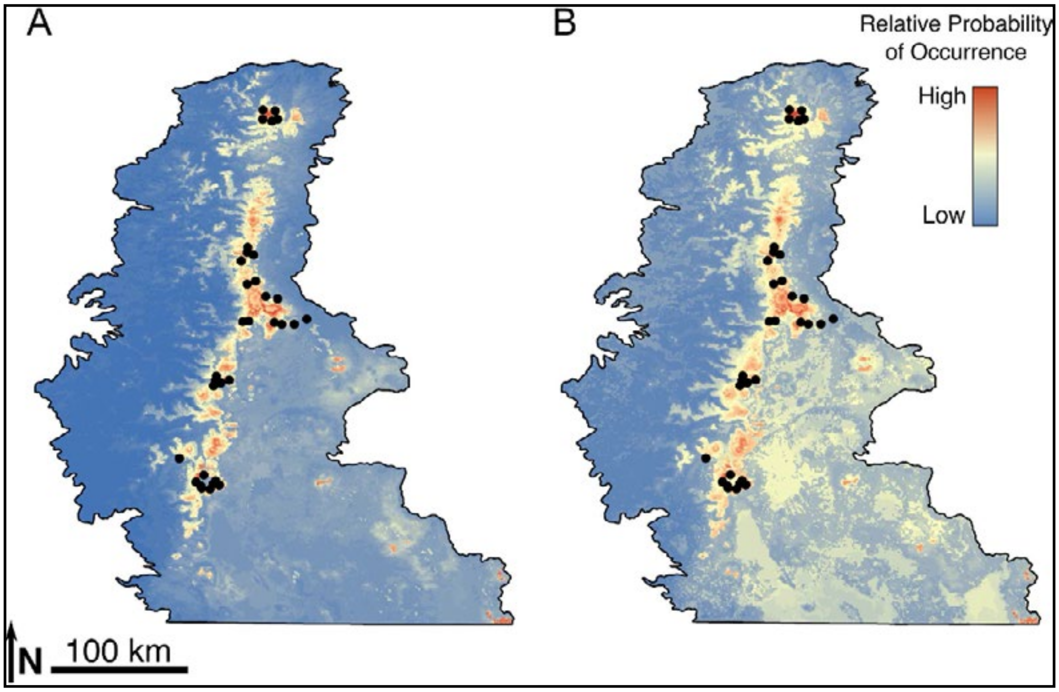

Figure 19. Relative probabilities of occurrence for SNRF in the Oregon Cascades based on 33 spatially independent verified records (2011–2016). Predictive surfaces are shown for Maxent models that used (A) default regularization and (B) optimal regularization. From Figure 6 in Quinn et al. 2018.

precipitation, and multiple consecutive years with persistent snow cover, and in subalpine parklands and upper montane forests.

Green et al. (in preparation) compiled recent detections and non-detections of SNRF throughout California and Oregon from carnivore surveys and opportunistic detections (Figure 20A). They then used these data to estimate habitat associations of SNRF across the entire range of the subspecies, model the probability of predicted occupancy (Figure 20B), and investigate how survey methods and camera placement affected the probability of detecting SNRF. They found SNRF were most likely to occupy environments with high measures of snow-water equivalent and low minimum temperatures. They also found that SNRF were less likely to be detected at cameras deployed on steep slopes or if bait was used, and more likely to be detected at cameras deployed on barren ground and those deployed for longer periods of time. These results also illuminated areas within the predicted range with high estimated occupancy by SNRF, but with limited or no survey effort, such as the large contiguous areas within and around Sequoia and Kings Canyon National Parks. These areas should be prioritized for additional surveys in the future (see section III.B.1.2.1. Extensive Tier 1 Information Needs: Presence, Absence, and Expansion).

Given the strong relationships among minimum temperature, snow-water equivalent, and SNRF occupancy, Green et al. (in preparation) suggested that it is likely that climate change may influence the range of SNRF over time. This work is ongoing and the results of the Green et al. model should be seen as preliminary. Final results will be forthcoming, including study area and population-wide estimates of potential SNRF abundance given current habitat and climatic conditions.

Stermer (in preparation) developed spatially explicit models for the entire historical range of the SNRF in Oregon and California and used these models to create predictive surface maps of SNRF occurrence, and to investigate landscape features and climate variables associated with SNRF occurrence (Figures 21, 22, 23, and 24). Incorporating verified SNRF detections obtained by numerous researchers and resource managers, Stermer (in preparation) employed Maxent modeling approaches (Phillips et al. 2006) to predict the probability of occurrence at the scale of the 10.4-km$^2$ hexagonal survey cells used by many researchers. Using the survey cell as

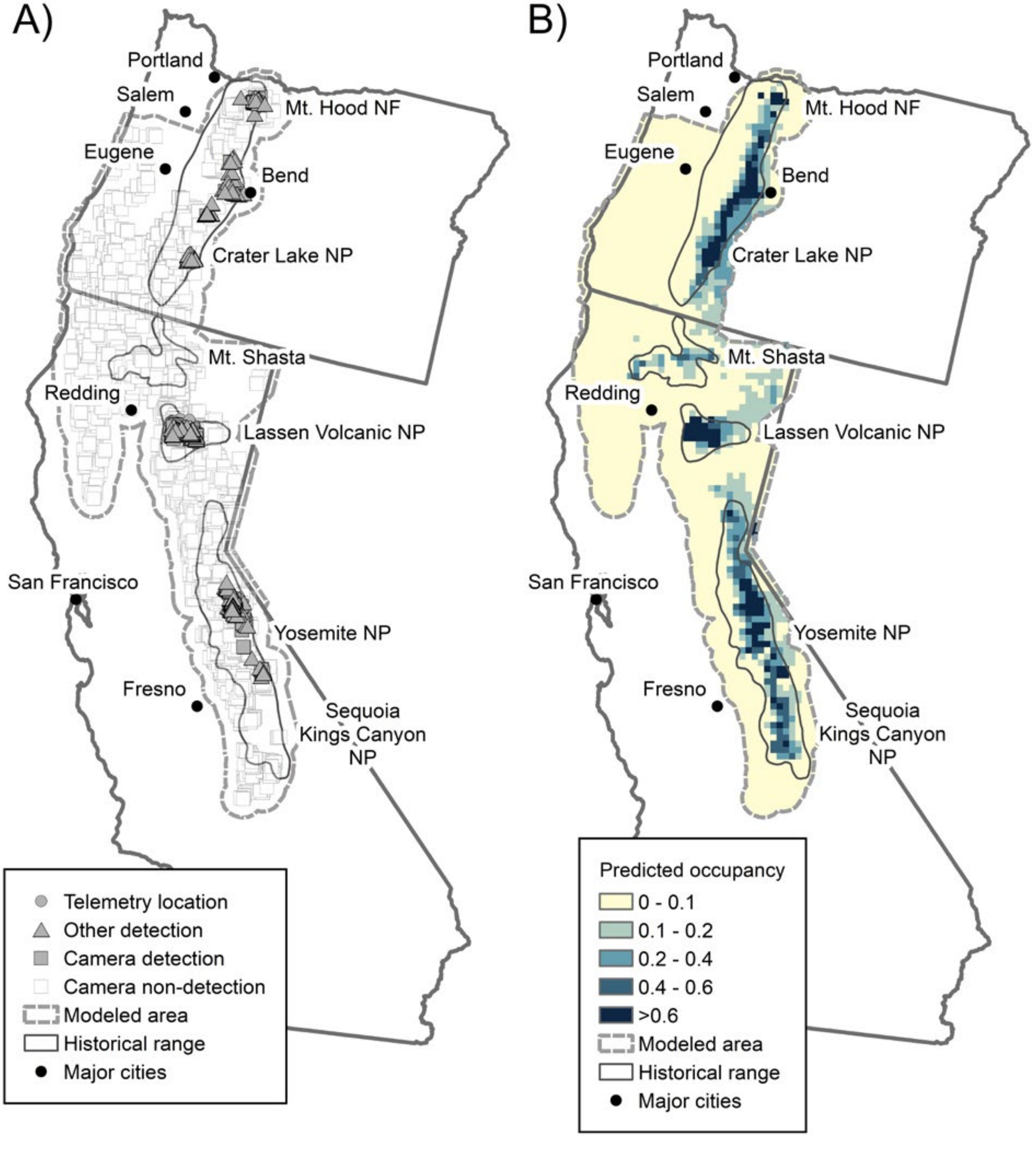

Figure 20. Data and results from Green et al.'s (in preparation) analysis of SNRF distribution in California and Oregon. In Figure 20A, gray-filled circles, squares, and triangles indicate telemetry locations, a detection of a SNRF on camera, or a detection of Sierra Nevada red fox through other methods, respectively. Open squares show the locations of camera deployments that did not detect SNRF. The dashed line encompassing all survey locations indicates the modeling extent. Figure 20B displays the output from the species distribution model performed by Green et al. (in preparation). Here, darker colors indicate a higher probability of occupancy by SNRF within the modeling extent. The black polygons in both figures indicate the previously identified range of the SNRF in California and Oregon (California: Grinnell et al. 1937 amended by Perrine et al. 2010; Oregon: historical range as depicted by Hall and Kelson 1959 and amended by genetic findings of Sacks et al. 2010).

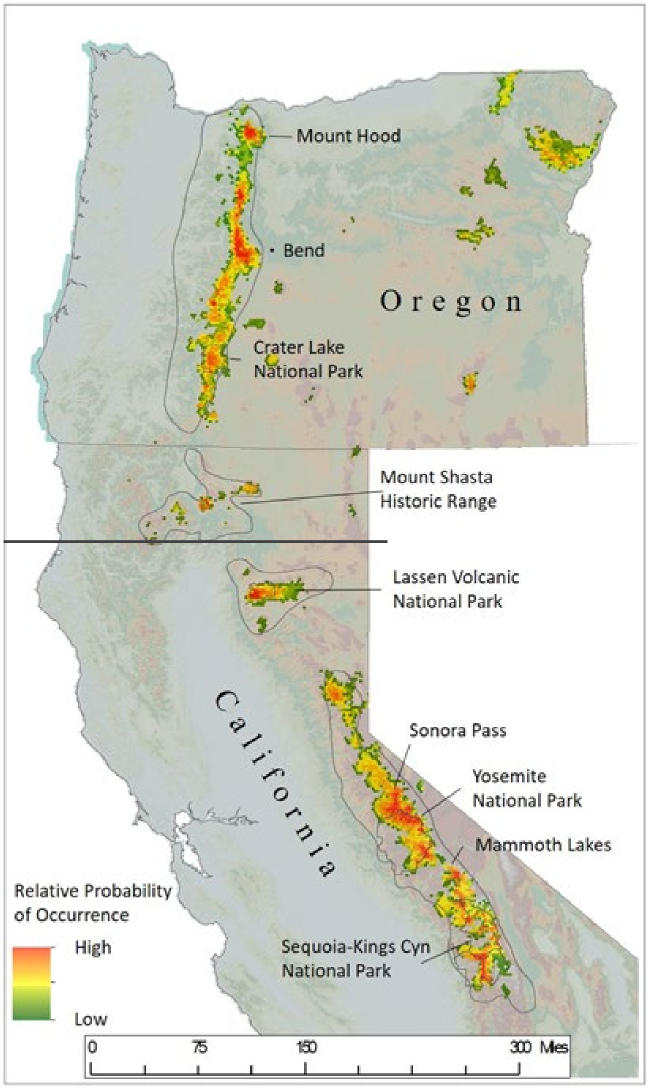

Figure 21. Maxent model results from Stermer (in preparation) identifying relative probabilities of occurrence throughout the known range of the SNRF in Oregon and California, based on **111** verified records collected between **2009–2020**. (Note that results of models are in draft form. Mapped regions and metrics in bold are subject to change.)

the spatial resolution for these models will facilitate identification of cells that should be targeted for future survey efforts.

Stermer (in preparation) used model results to estimate the probable contemporary distribution of the SNRF, including regions where occupancy has not yet been verified, such as Sequoia and Kings Canyon National Parks in the south and Carson Pass in the north of the SNRF's historical range within the Sierra Nevada. For each SNRF population (Lassen, Sierra Nevada, and Oregon), Stermer (in preparation) estimated a contemporary distribution by applying a restrictive threshold to convert the initial model of relative probability of occurrence (Figures 22A, 23A, and 24A) into a binary estimate of presence and absence (Figures 22B, 23B, and 24B). This restrictive threshold approach (ClogLog, 10th percentile training presence) is commonly used in Maxent models and conservatively assumes that the 10% of detections that occur in the lowest quality habitat do not accurately represent the habitat associations of the species. Therefore, the threshold omits the habitat suitability values contributed to the model by these detections. In the resulting model, all the values less than the calculated threshold are assigned as non-habitat or absence, and all the values greater than the threshold are assigned as potential habitat or presence.

The estimated contemporary range of each population (Figures 22B, 23B, and 24B) was informed by model results and expert opinion. Estimated range polygons were drawn to encompass the maximum extent of predicted presence within each population. These results are preliminary and will continue to be refined as models are revised with additional survey data. The estimated ranges for the Lassen and Sierra Nevada populations will be submitted to CDFW's California Wildlife Habitat Relationships System as an update to CDFW's current range maps for SNRF in California.

Stermer (in preparation) identified a strong relationship between SNRF occurrence and the amount and seasonal duration of snow cover, and this result was consistent throughout the SNRF range in Oregon and California. Because climate change is expected to result in reduced snow cover throughout the high-elevation areas where SNRF occur (Dettinger et al. 2018; Mote et al. 2019), this finding suggests a concern for the future suitability of habitat in those areas. The results of Stermer's models are preliminary, and will be expanded to

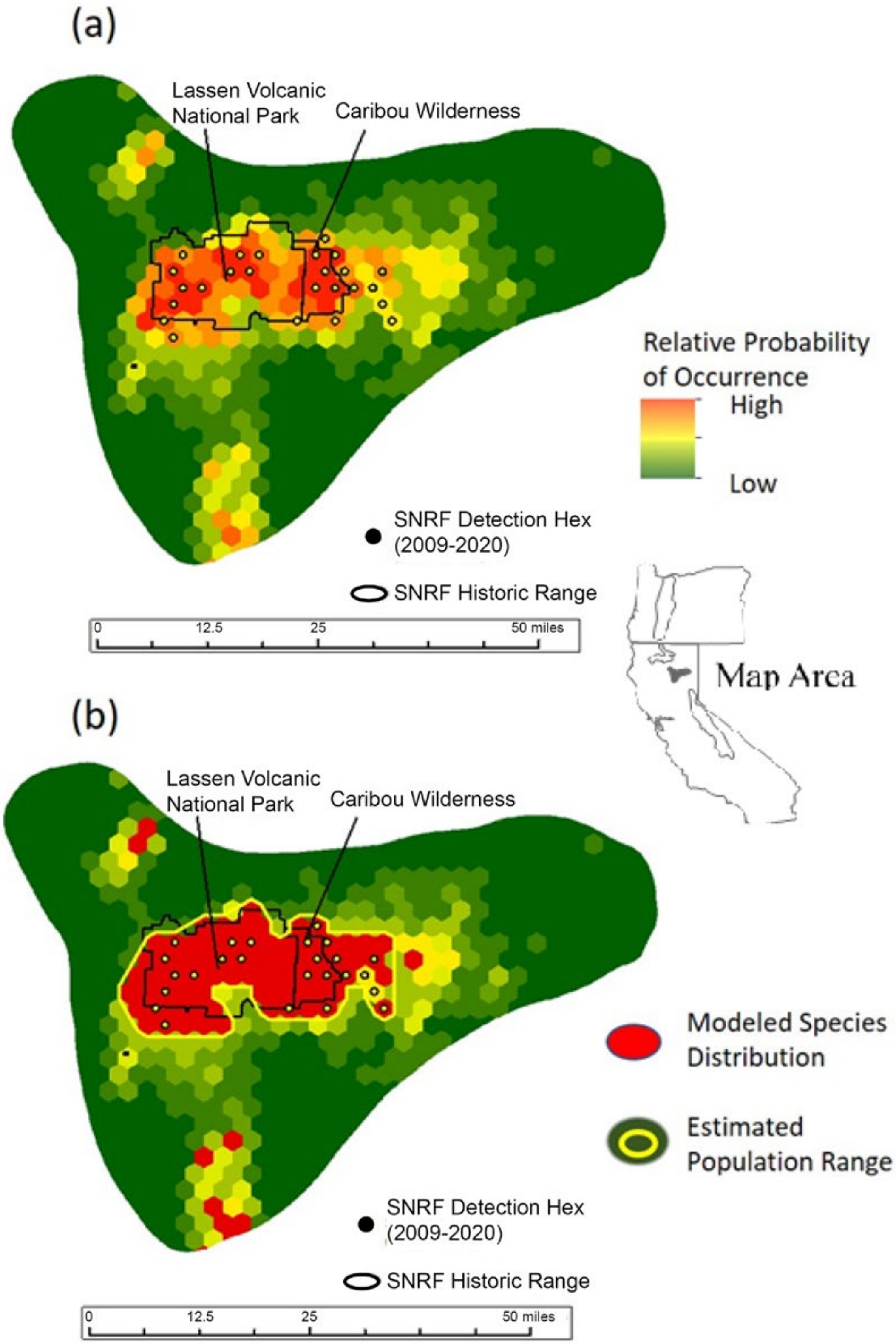

Figure 22. Predictive surface maps from Stermer (in preparation) identifying relative probabilities of occurrence and distribution for SNRF within their historical range in the Lassen Peak region. Figure 22A identifies relative probabilities of SNRF occurrence based on **26** verified records **(2009–2020)**. Predicted distribution (Figure 22B) is based on applying a restrictive threshold (CloglLog threshold > **38.4%**; 10 percentile training presence). (Note that results of models are in draft form. Mapped regions and metrics in bold are subject to change.)

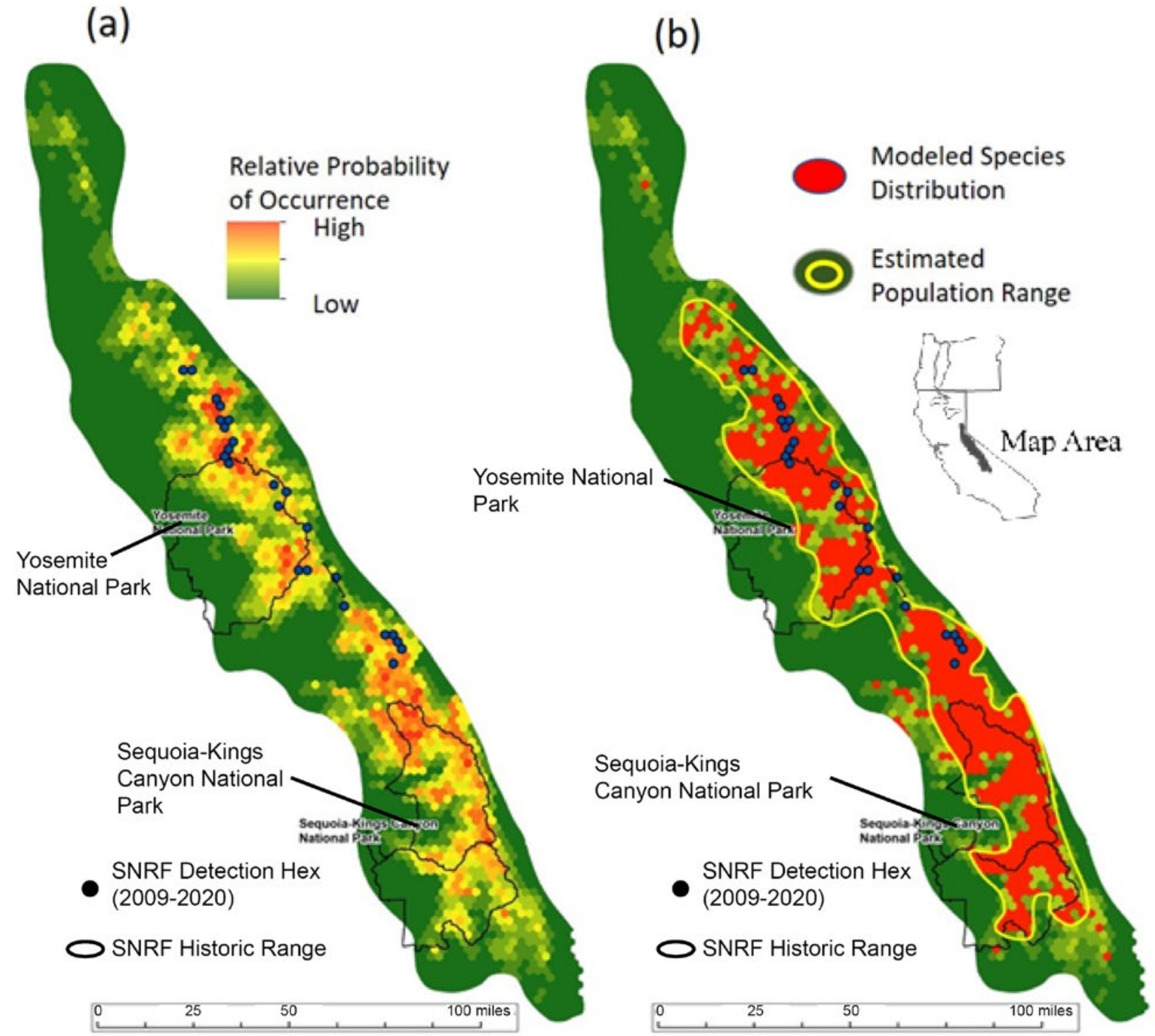

Figure 23. Predictive surface maps from Stermer (in preparation) identifying relative probabilities of occurrence and distribution for SNRF within their historical range in the Sierra Nevada. Figure 23A identifies relative probabilities of SNRF occurrence based on **22** verified records **(2009–2020)**. Predicted distribution (Figure 23B) is based on applying a restrictive threshold (ClogLog threshold > **34.5%**; 10 percentile training presence). (Note that results of models are in draft form. Mapped regions and metrics in bold are subject to change.)

project potential habitat loss and refugia in light of climate change.

The typical elevational distribution of SNRF varies by region (Figure 25) because the habitat types occupied by SNRF occur at lower elevations in the northern latitudes of their range. In the Sierra Nevada, the mean elevation of survey cells with SNRF detections is 3,173 m (SD = 280 m), with a range from 2,607 m to 3,651 m. In the Lassen study area, survey cells with SNRF detections range in elevation from 1,750 m to 2,631 m with a mean elevation of 2,068 m (SD = 191 m). In Oregon, survey cells with SNRF detections range from 1,034

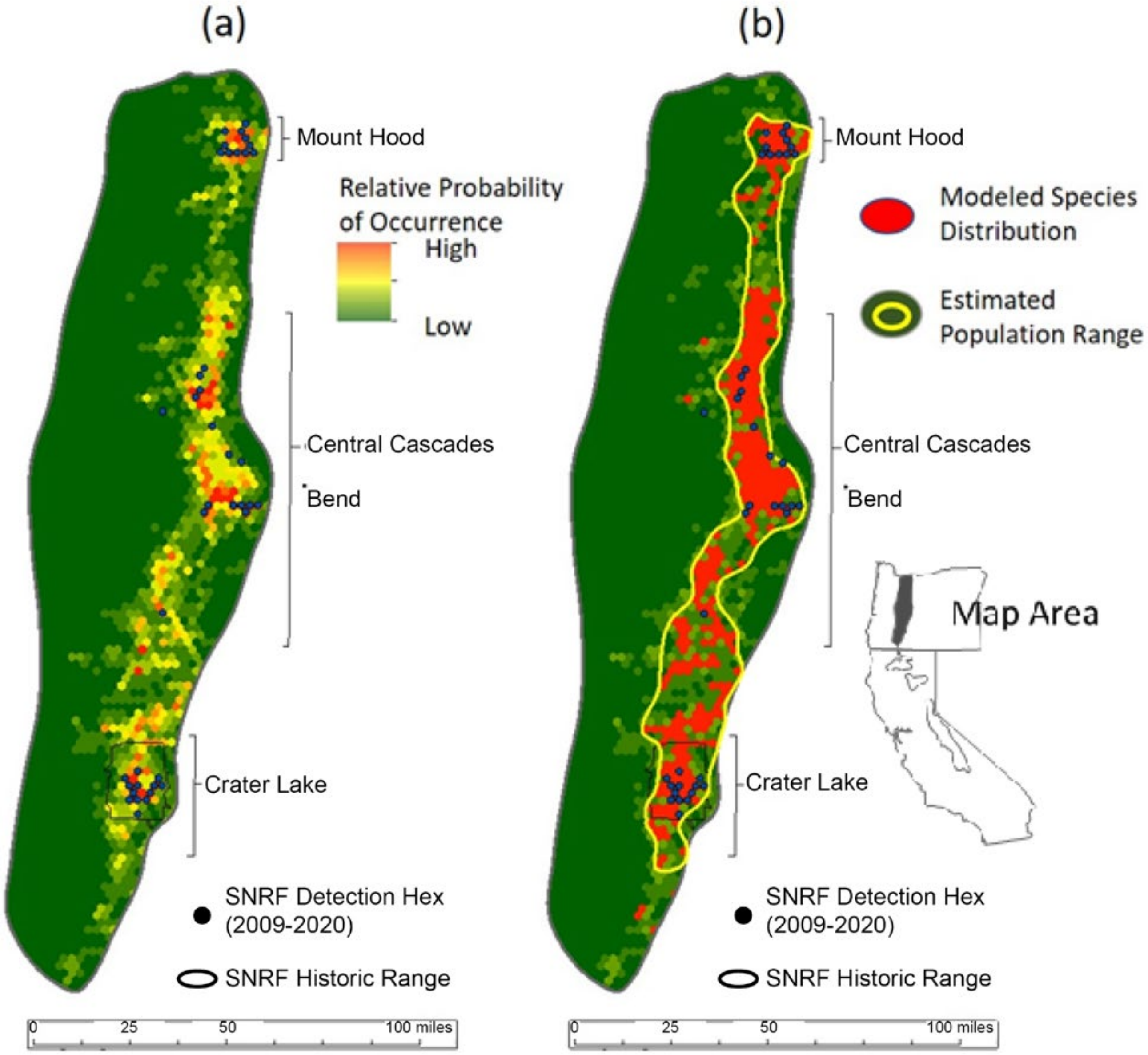

Figure 24. Predictive surface maps from Stermer (in preparation) identifying relative probabilities of occurrence and distribution for SNRF within their historical range in Oregon. Figure 24A identifies relative probabilities of SNRF occurrence based on **40** verified records **(2009–2020)**. Predicted distribution (Figure 24B) is based on applying a restrictive threshold (CloglLog threshold > **18.2%**; 10 percentile training presence). (Note that results of models are in draft form. Mapped regions and metrics in bold are subject to change.)

m to 2,220 m in elevation with a mean elevation of 1,720 m (SD = 285 m). In the Central Cascades study area, point detections of genetically verified SNRF have occurred only above 1,400 m[3].

Research and monitoring continue throughout the range to determine the current distribution of SNRF. Section II.D. Current Status of Known Populations

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[3] Detection elevations were calculated at the scale of the 10.4-km2 survey cell rather than for individual detection points. Elevations were averaged across each survey cell, and mean elevation per population was calculated from the mean elevations of all survey cells with detections in each population (C. Stermer, CDFW, unpublished data).

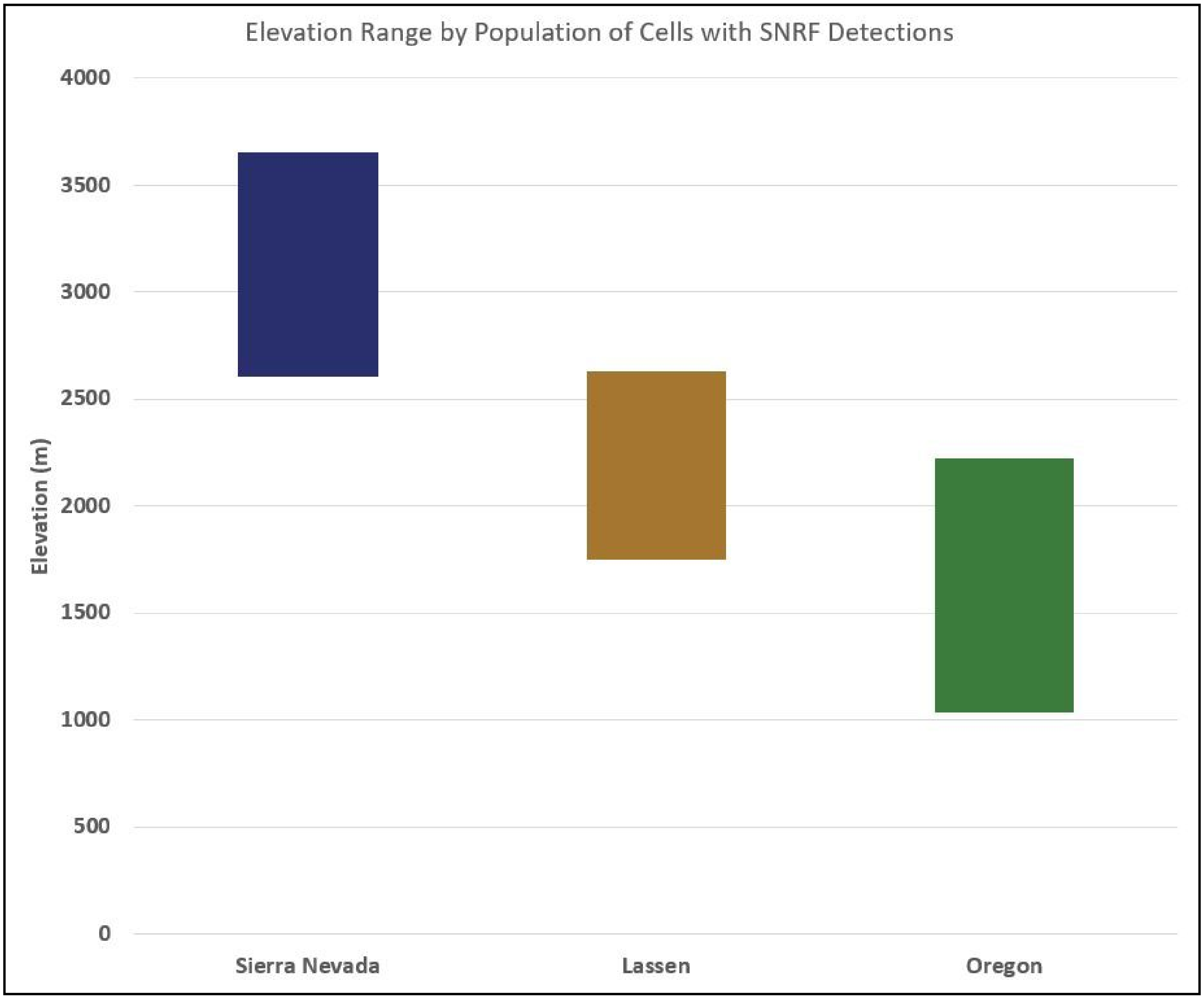

Figure 25. Elevation range by population of survey cells with SNRF detections (C. Stermer, CDFW, unpublished data).

describes the distribution of location data from each population as of the writing of this Strategy.

## II.C.2. DENSITY

During 2010–2017, Quinn et al. (2019) used spatial capture-recapture with fecal DNAsamples to estimate density in the Sonora Pass study area. During a period of apparent population growth, density remained relatively constant at approximately 4 foxes/100 km2 with a range from 2 to 5 foxes/100 km2. This low density estimate is consistent with the large home-range sizes observed for SNRF (Perrine 2005; Carlson et al. 2019; ODFW, unpublished data; C. Quinn, UC Davis, unpublished data), and may result from the resource limitations of their environment (Quinn et al. 2019). However, although SNRF may always have existed at relatively low population densities (Grinnell et al. 1937; Schempf and White 1977; Perrine et al. 2010), we cannot assume that current densities are equivalent to historical densities when abundance

Figure 26. A day rest site on a rock outcrop in the Lassen study area. Photo courtesy of John Perrine, August 1998.

Figure 27. A day rest site in manzanita scrub in the Lassen study area. Photo courtesy of John Perrine, June 1999.

Figure 28. A day rest site among red fir saplings in the Lassen study area. Photo courtesy of John Perrine, August 1998.

was greater and other factors, such as prey or competitor densities, may have been different.

## II.C.3. HABITAT ASSOCIATIONS

Perrine et al. (2010) summarized the historical literature describing habitat relationships of the SNRF in California and Oregon. Briefly, SNRF occurrence seems to have been associated with more open vegetation types (woodlands, meadows, and fell fields) and barren areas in alpine, subalpine, and montane zones (Bailey 1936; Grinnell et al. 1937; Ingles 1965; Schempf and White 1977; Perrine 2005). SNRF and other montane foxes forage for small mammal prey in meadows, forest openings, and barren ridges (Bailey 1931; Grinnell et al. 1937; Aubry 1983), and use a variety of structures for day rests, including crevices in talus slopes or rock outcrops (Figure 26), cavities under fallen logs or snow-laden boughs, and gaps in manzanita (Figure 27), other shrubs, or dense stands of saplings (Figure 28; Perrine 2005). Den-site selection is described below in section II.C.4.

Contemporary inferences about SNRF habitat associations rely on location data from noninvasive detections, along with telemetry or GPS locations from a small number of collared individuals. These data can be biased by sampling method and should be interpreted with caution. For example, remote camera detections may represent locations where SNRF are more detectable, rather than habitat attributes for which they select. Similarly, opportunistic observations, scat samples, and telemetry locations may be skewed toward areas that humans are able to access or where SNRF are already known to occur.

Available habitat varies substantially among the study areas occupied by SNRF, precluding broad conclusions about habitat selection at the range-wide level. This variation is also evident among survey cells occupied by SNRF in each population. Average tree canopy coverage of occupied cells is greater than 30% in the Lassen and Oregon

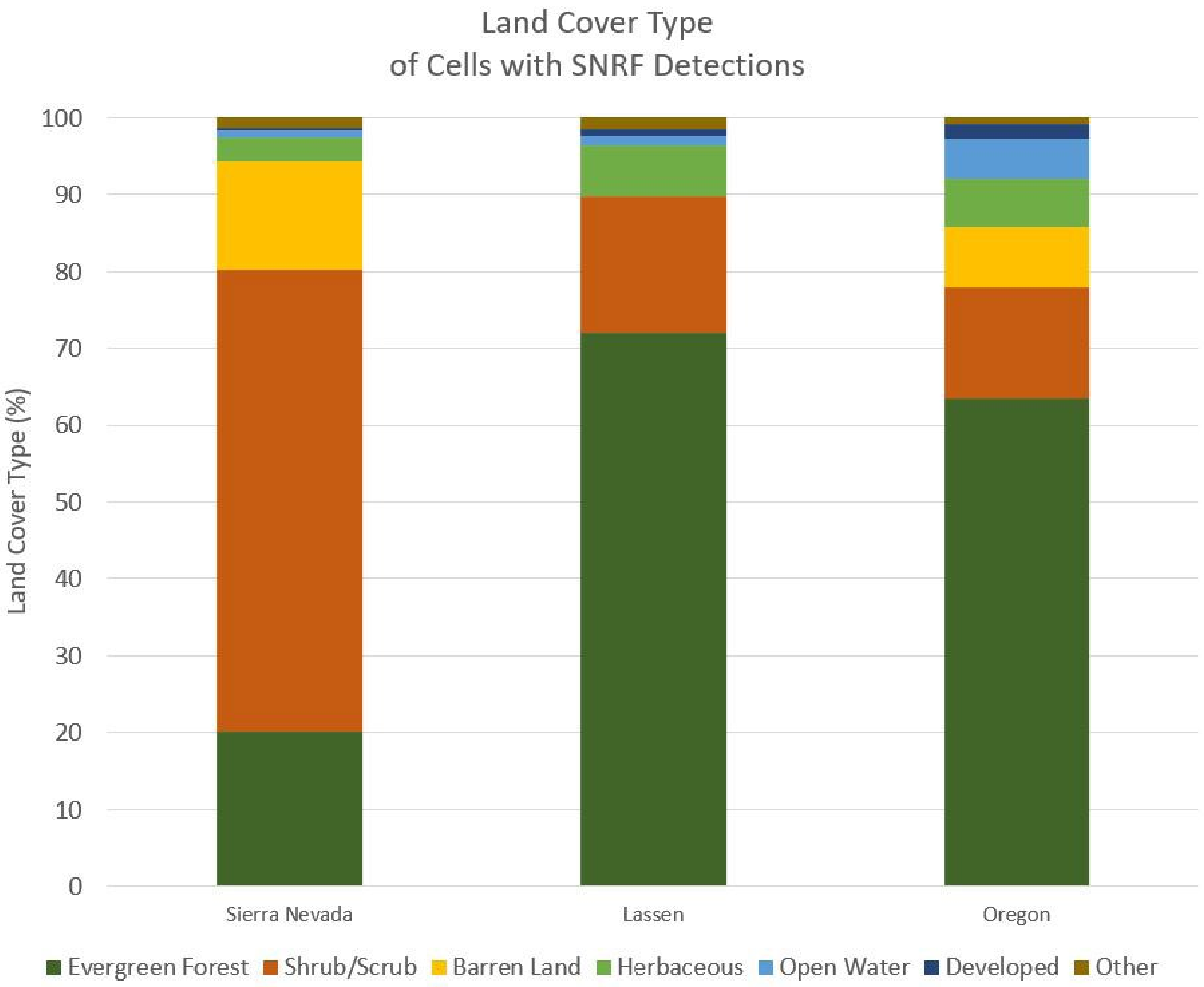

Figure 29. Proportion of land cover types (from National Land Cover Database) of survey cells with SNRF detections in each population (C. Stermer, CDFW, unpublished data).

populations and less than 10% in the Sierra Nevada population. The dominant land cover type of occupied cells is evergreen forest in the Lassen and Oregon populations (72% and 63% respectively) and shrub/scrub in the Sierra Nevada population (60%). Occupied cells in the Sierra Nevada population contain a higher proportion of land classified as barren (14%) than occupied cells in the Lassen and Oregon populations (0% and 8% respectively; Figure 29; C. Stermer, CDFW, unpublished data).

Contemporary habitat selection by SNRF may be affected by numerous factors such as climate change, competition, development, and habituation, such that areas where SNRF are found currently may not be representative of optimal habitat (Perrine et al. 2010). With these limitations in mind, we describe our current understanding of available habitat and habitat used by SNRF in each population.

## II.C.3.1. LASSEN

LVNP and the surrounding Lassen National Forest

Figure 30. An area where SNRF have been detected in western LVNP. Photo courtesy of CDFW, September 2019.

Figure 31. A forested area where SNRF have been detected in the Caribou Wilderness. Photo courtesy of CDFW, October 2015.

are dominated by conifer forests of mountain hemlock, whitebark pine, red fir, lodgepole pine, white fir, and Jeffrey pine, with predominant species stratified by elevation. Montane chaparral and wet meadows also occur in the study area. The alpine zone in LVNP is characterized by barren volcanic peaks and ridges, including Lassen Peak, a dormant plug dome volcano. Summers are typically warm and dry and winters are cool and wet, with the majority of the annual precipitation occurring as snow. Snowpack is often substantial and long-lasting (Perrine 2005).

Preliminary analysis of location data from the 3 collared SNRF using western LVNP in 2018–2019 showed habitat use consistent with that found in Perrine's (2005) study: regular use of high-elevation forests, subalpine woodlands, and barren areas near or above tree-line, and significant use of mid-elevation forests in the winter (Figure 30). One SNRF collared during 2018–2021, however, inhabited the Caribou Wilderness area, a largely forested plateau which lacks the extensive terrain over 2,100 m that characterizes western LVNP (Figure 31). According to data from CDFW remote camera and scat surveys during 2013–2019, SNRF used the Caribou Wilderness year-round. Analysis of remote camera photos and scats collected since 2015 also indicates regular summer use of the eastern portions of LNVP, which, similar to the Caribou Wilderness, primarily support mid-elevation forest types and lack subalpine and alpine habitats.

## II.C.3.2 SIERRA NEVADA

The majority of precipitation in the high-elevation Sierra Nevada falls as snow during the winter, and the amount of precipitation varies greatly between years. Storms can bring winds up to 240 km/hr, scouring snow from exposed alpine ridges and passes. Summers are typically short and dry (Major 1977). A mosaic of vegetated, barren, and permanently snow-covered areas characterizes the alpine and subalpine zones of the Sierra Nevada (Figure 32). Vegetation types include fell fields, dry and wet meadows, scrub, and patchy, open woodland or krummholz dominated by whitebark pine and mountain hemlock (Verner and Purcell 1988; Fites-Kaufman et al. 2007).

The Sierra Nevada contains substantially more areas classified as alpine or subalpine than study areas in Lassen and Oregon. SNRF in the Sierra Nevada have been detected mostly in alpine and subalpine zones, and appear to occupy these high elevations year-round (Hatfield et al. 2020; CDFW, unpublished data; NPS, unpublished data; C. Quinn, UC Davis, unpublished data). Most SNRF detections in the Sierra Nevada were collected

Figure 32. A ridge where SNRF have been detected in the Sonora Pass study area. Photo courtesy of Cate Quinn, July 2017.

noninvasively, limiting the scope of inferences about habitat selection.

Surveys in the Ritter Range and Mono Creek study areas have focused on high-elevation passes and ridges in an effort to maximize detectability and long-term camera function in remote wilderness (Hatfield et al. 2020). All SNRF detections in these study areas were at elevations over 3,000 m. Of 21 camera detections, 17 were on barren passes or wind-scoured ridges (Figure 33). These findings should not be interpreted as demonstrating selection by SNRF of these geographic features or elevation zones, but do confirm that SNRF use barren alpine terrain in the Sierra Nevada and can be found year-round at elevations up to the crest of the range. SNRF in the Sonora Pass and YNP study areas have also been detected year-round at the highest elevations available, including the summit of Sonora Peak (C. Quinn, UC Davis, personal communication 2020). Of 13 detections in the YNP study area during 2014-2020, 11 were above 3,048 m in elevation (NPS, unpublished data).

### II.C.3.3. OREGON

The Cascades crest in Oregon consists of forested highlands punctuated by a series of volcanic peaks, some capped with permanent snowfields. Below these peaks, open meadows are interspersed with dwarf shrubs and whitebark pine, subalpine fir, and mountain hemlock stands. At lower subalpine and upper montane elevations, forests of mountain hemlock, Pacific silver fir, and noble fir typify the wetter western slopes, whereas drier eastern slopes support forests of lodgepole and ponderosa pine (Quinn et al. 2018).

Preliminary analysis of home ranges in the Central Cascades study area suggested that GPS-collared SNRF selected for subalpine mountain hemlock

Figure 33. A barren alpine pass where SNRF have been detected in the Mono Creek study area. Photo courtesy of Brian Hatfield, May 2018.

Figure 34. An area where SNRF have been detected in the Central Cascades study area. Photo courtesy of Jamie Bowles, November 2018.

woodlands and alpine-montane grasslands (Figure 34; ODFW and Wildlife Ecology Institute, unpublished data). As in the Sierra Nevada, habitat selection in the Mt. Hood and CLNP study areas is difficult to infer from the limited noninvasive detection data collected to date.

## II.C.4. DEN-SITE SELECTION

Red foxes often use multiple dens during the breeding season (Storm et al. 1976). The term "natal den" refers to the den where pups are born and remain for their first several weeks; after this initial period pups may be moved several times to other dens during the remainder of their dependency. Although we have little information about den-site selection in SNRF, in general, dens seem similar in structure to those of low-elevation red foxes and other canids. Grinnell et al. (1937) described SNRF dens as natural openings in talus slopes. Researchers in the Lassen study area identified 2 dens in 2018 and 2019. Both dens were located at approximately 2,800 m in elevation in rocky, subalpine areas with scattered whitebark pine and mountain hemlock. The den located in 2018 was an earthen tunnel dug under a rock outcrop with a southeast aspect (Figure 35). The den located in 2019 faced south and consisted of several natural crevices in exposed bedrock (Figure 36). The 2 dens were approximately 2.1 km apart (CDFW, unpublished data). In the Central Cascades study area, researchers have observed both rock and earthen natal dens at varying montane elevations and in varying land-cover types (ODFW, unpublished data). Characteristic rock dens consisted of numerous natural entrances among boulders or in lava flows (Figure 37); 1 rock den was located in a manmade rock pile. Earthen dens were found in loose soil, rotted or burnt tree stumps or roots, or old marmot dens (Figure 38). In both the Lassen and Central Cascades study areas, SNRF have reused dens in multiple years. In the Lassen population, a mated pair moved its pups late in summer 2019 from their natal den to the den used in 2018. In the Central Cascades study area, a den was used as a rest site one year and a natal den the next.

Figure 35. SNRF den site observed in the Lassen study area in 2018 and re-used in 2019. Photo courtesy of CDFW.

Figure 36. SNRF den site observed in the Lassen study area in 2019. Photo courtesy of CDFW.

## II.C.5. HOME RANGES

SNRF use very large home ranges (Table 1), perhaps due to the relatively low productivity of their environment (Perrine et al. 2010; Walton et al. 2017). In interpreting the results described below, it is important to remember that estimates vary by study area, time period, and data type, and that home-range sizes of non-breeding individuals are typically larger than those of breeding adults.

Table 1. Estimated home-range sizes (95% minimum convex polygon) of SNRF in the Lassen, Sonora Pass, and Central Cascades study areas (Perrine 2005; CDFW, unpublished data; C. Quinn, UC Davis, unpublished data; ODFW, unpublished data).

| Source | Study Area | N (sex) | Reproductive Status | Time Period | Location Method | Home Range Estimation Method | Home-range Size (km2) |
|---|---|---|---|---|---|---|---|
| Perrine 2005 | Lassen | 1 (M), 4 (F) | non-breeding | summer | telemetry | 95% MCP | 25.6 |
| Perrine 2005 | Lassen | 1 (M), 4 (F) | non-breeding | winter | telemetry | 95% MCP | 32.6 |
| CDFW unpublished data* | Lassen | 1 (F) | breeding | summer | GPS | 95% MCP | 23.0 |
| CDFW unpublished data* | Lassen | 1 (F) | breeding | winter | GPS | 95% MCP | 69.4 |
| CDFW unpublished data* | Lassen | 1 (F) | non-breeding | summer | GPS | 95% MCP | 112.4 |
| CDFW unpublished data* | Lassen | 1 (F) | non-breeding | winter | GPS | 95% MCP | 126.4 |
| C. Quinn unpublished data | Sonora Pass | 1 (F) | non-breeding | Jan-Sept | Argos | 95% MCP | 44.0 |
| C. Quinn unpublished data | Sonora Pass | multiple pairs | breeding | pooled across multiple years | scat | 95% MCP | 22.0 |
| ODFW unpublished data* | Central Cascades | 3 (M), 5 (F) | both breeding and non-breeding | variable based on collar deployment | GPS | 95% MCP | 135.0 |

*preliminary results

Figure 37. Rock den site observed in the Central Cascades study area in July 2019. Photo courtesy of ODFW.

Perrine (2005) estimated the average home-range size of 5 non-breeding animals in Lassen as 25.6 km2 in summer and 32.6 km2 in winter (95% minimum convex polygon [MCP] using VHF data). CDFW (unpublished data) found that the large home range of a non-breeding female in Lassen was similar in size between summer (112.4 km2) and winter (126.4 km2), whereas a breeding female's home range decreased from 69.4 km2 in winter to 23.0 km2 in summer (95% MCP using GPS data). In the Sonora Pass study area, 1 non-breeding female used a home range of 44.0 km2 during January–September (95% MCP using Argos satellite data), whereas breeding SNRF used minimum home ranges of 22.0 km2 (95% MCP estimated from scats from breeding pairs collected across multiple years; C. Quinn, UC Davis, unpublished data). Tentative estimates of home-range sizes for SNRF in the Central Cascades study area in Oregon are larger than those reported in California, averaging approximately 135.0 km2 (95% MCP using GPS data; ODFW, unpublished data)[4].

Figure 38. Earthen den site observed in the Central Cascades study area in 2017. Photo courtesy of ODFW.

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[4] The large home-range estimates from the Central Cascades study area relative to SNRF home ranges estimated in other study areas may result from differences in study design such as the different time period of the estimates (full-year rather than partial-year or seasonal) or the data type (GPS locations rather than scat, telemetry, or Argos satellite locations). SNRF home-range estimates from the Central Cascades study area should be regarded as preliminary, and are presented here as additional evidence that SNRF use large home ranges relative to low-elevation red foxes.

By contrast, MCP estimates of mean home-range sizes for low-elevation red fox populations in North America ranged from 4.3 to 16.1 km2 (Voigt and Tinline 1980; Jones and Theberge 1982; Voigt 1987; Harrison et al. 1989; Lewis et al. 1993). Consistent with the hypothesis that red foxes inhabiting lower productivity environments use larger home ranges, the larger estimates in the literature came from populations at higher latitudes (e.g., eastern Maine, northwestern British Columbia).

## II.C.6. SEASONAL VARIATION IN HOME RANGES

Seasonal migration in SNRF is unlikely as it would conflict with the territorial mode of space use characteristic of the canid family. Perrine (2005) suspected a seasonal increase in home-range size of 5 collared SNRF in Lassen to encompass lower elevations in winter; Grinnell et al. (1937:388) also remarked that "there is a marked tendency for certain individuals of this species to descend to middle altitudes for the winter season." More recent location data from the Lassen population and from the Sonora Pass study area suggest that SNRF may use larger home ranges in winter than summer, but confirm that they occupy high elevations year-round (Figure 39; Quinn et al. 2019; Hatfield et al. 2020; CDFW, unpublished data).

## II.C.7. DISPERSAL

Trewhella et al. (1988) conducted a meta-analysis of mean dispersal distances for juvenile male red foxes from non-montane populations in North America. Straight-line distances ranged from 17.4 to 43.5 km. Allen and Sargeant (1993) found that 57% of red foxes that were tagged and recovered in North Dakota had dispersed; recovery distance ranged from 0 to 302 km, was greater for males, and increased with age class. Red foxes are capable of dispersing hundreds of kilometers; in the midwestern U.S., male red foxes have dispersed as far as 346 km (Storm et al. 1976) and 395 km (Ables 1965).

Dispersal behavior in populations of montane red foxes is not currently well studied, though Aubry (1983) detected an 8-km dispersal of a collared female Cascade red fox and Akins (2017) found 2 closely related Cascade red foxes that had traveled more than 90 km apart. A male SNRF in the Mono Creek study area dispersed there from the Sonora Pass study area, where he had been detected the previous fall, traveling at least 120 linear km (and likely a much greater actual distance given the intervening mountainous terrain; Figure 40). As dispersal distance is thought to be positively correlated with home-range size (Voigt 1987), long-distance dispersal movements may be common in SNRF. Distribution models predict nearly continuous

Figure 39. A barren alpine ridge in the Mono Creek study area where SNRF were detected in February and April 2018. Photo courtesy of Brian Hatfield, May 2018.

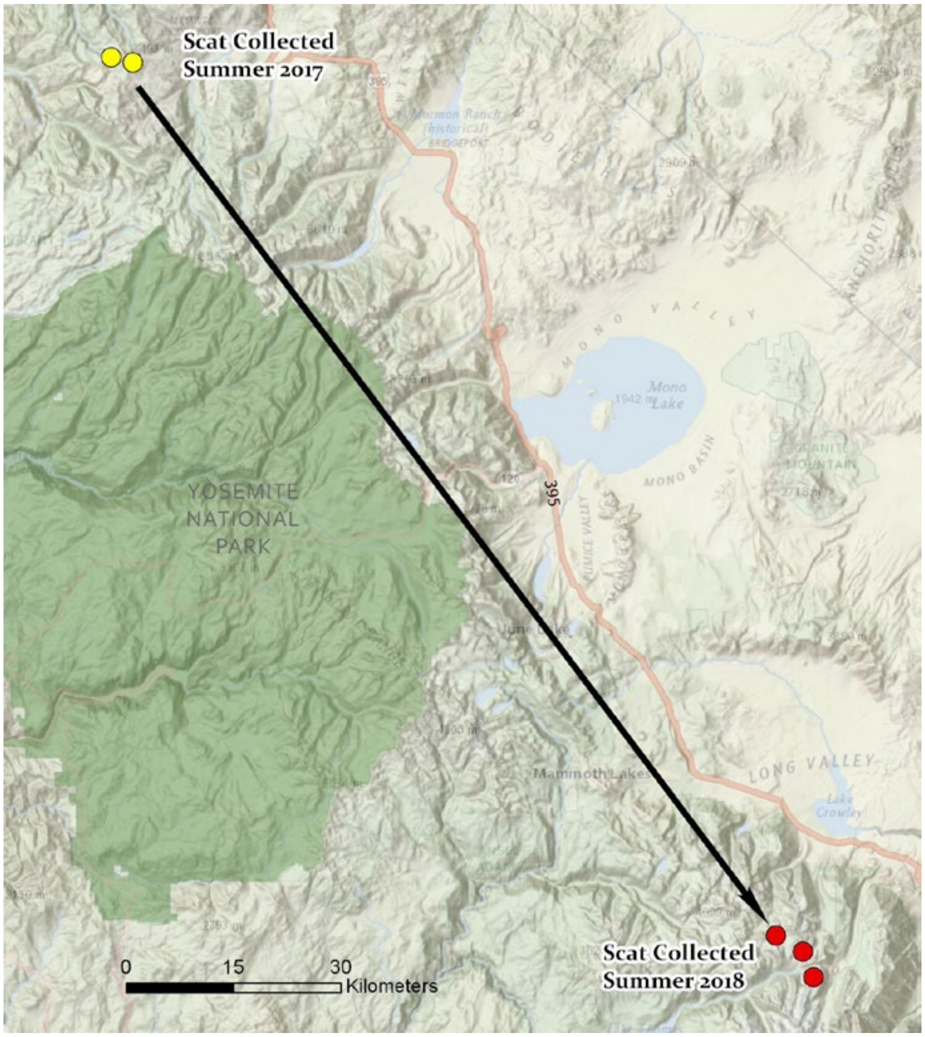


Figure 40. Locations of scat samples collected from the same male SNRF in September 2017 (Sonora Pass study area) and June 2018 (Mono Creek study area), at least 120 linear km apart. From Figure 8 in Hatfield et al. 2020.

suitable habitat throughout the historical range in the Sierra Nevada (Cleve et al. 2011; Green et al. in preparation; Stermer in preparation) and along the crest of the Oregon Cascades south of Mt. Jefferson (Quinn et al. 2018), suggesting that long-distance dispersal is possible within these regions, though barriers may exist.

# II.D. CURRENT STATUS OF KNOWN POPULATIONS

## II.D.1. CURRENT POPULATION STATUS: LASSEN

### II.D.1.1. DISTRIBUTION

Grinnell et al. (1937:381) described the SNRF populations in California's Cascades and Klamath Mountains as occurring on the "mountain masses of which Lassen Peak and Mount Shasta are the highest points." Historically, the easternmost known extent of the Lassen population was near Eagle Lake, and the westernmost known extent was approximately 5 km west of Mineral, California (Grinnell et al. 1930). The average elevation of detections was 1,950 m, with a range from 1,310 m to 2,590 m (Schempf and White 1977).

The Lassen population currently occurs in the vicinity of LVNP and the adjacent Lassen National Forest (including the Caribou Wilderness) in northern California (Figure 3). The range of the Lassen population seems to have contracted over the past century. Whereas SNRF continue to be detected throughout much of LVNP and adjacent portions of the Lassen National Forest, they may be absent from areas of their former range east of State Highway 44 (e.g., Crater Mountain and the ridges and peaks near Eagle Lake). There have been no verified detections of SNRF on or near Mt. Shasta or in the Klamath Mountains since the 1930s. However, occasional detections indicate that SNRF may sometimes use or disperse to or from broader areas (Figure 41). In March 2013, a SNRF was detected by a remote camera near Humbug Summit (K. Moriarty, USFS, unpublished data), over 30 linear km south of areas near Mineral where they have been consistently detected. Other remote

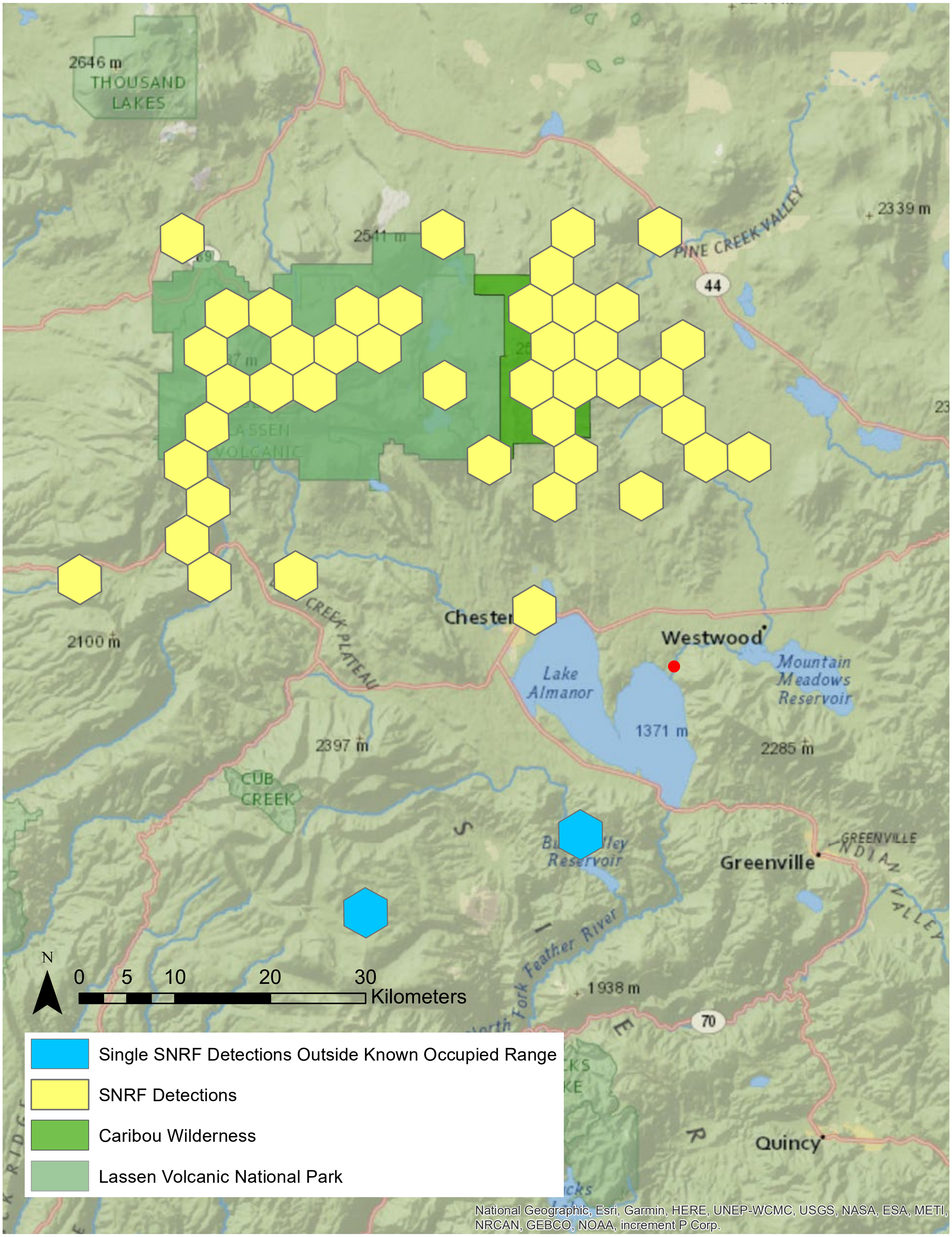


Figure 41. Locations of SNRF detections outside the main areas of known occurrence in the Lassen Peak region.

cameras set in the area during 2013–2015 did not detect SNRF. In March 2019, a SNRF was detected by a remote camera near Butt Valley Reservoir, southwest of Lake Almanor (B. Johnson, Collins Pine Company, unpublished data).

## II.D.1.2. DEMOGRAPHICS AND GENETICS

Several lines of evidence indicate that the current Lassen population is small, inbred, and isolated from external gene flow. After capturing 5 SNRF from 1998 to 2000, Perrine (2005) recaptured those individuals, but captured no additional individuals during 2000–2002. CDFW attempted to capture SNRF from 2013 to 2015 without success. During 2018–2020, CDFW captured 7 SNRF (1 male, 6 females) and recaptured 4 of those foxes at least once. Few additional uncollared SNRF were detected by remote cameras at the capture sites during Perrine's (2005) and CDFW's studies. CDFW's efforts to collect scat and hair samples from 2007 to 2019 yielded 736 genetically confirmed SNRF samples representing a total of 36 individuals, with an average of 6.5 individuals detected annually and no more than 10 individuals detected in any calendar year.

High genetic distances to other SNRF populations indicate that this population is isolated (Perrine et al. 2007; Sacks et al. 2010a; Quinn 2018), and genetic samples exhibit low heterozygosity (0.42; C. Quinn, UC Davis, unpublished data 2008–2010). The genetic effective population size of native individuals was estimated at 2.1 (95% CI 1.8–2.4; Quinn 2018). This extremely low value suggests that the Lassen population is at high risk of further loss of genetic diversity, which could lead to inbreeding depression and reduced fitness.
Pedigree reconstruction confirmed that the population is highly inbred, including full-sibling matings (C. Quinn, UC Davis, unpublished data). Reproduction in the population may be infrequent, possibly due to inbreeding depression, limited prey availability, or both. Though 4 of the 5 collared SNRF that Perrine studied during 1998–2002 were female, none of the animals reproduced during the 4-year study period (Perrine 2005). The only breeding detected in 2018 and 2019 occurred between pairs of siblings (CDFW, unpublished data), implying that there may be few adult SNRF in the Lassen population and those that are present are closely related to one another. Low reproductive rates and documented breeding between full siblings provide further reason to suspect inbreeding depression in this population.

In 2011, genetic sampling (hair and scat) revealed that a male red fox with mixed native Sacramento Valley and eastern (i.e., possibly fur farm) ancestry had immigrated into the population. All individuals genetically identified via scat and hair samples from 2016 to 2019–the entire known population during that time–were descendants of that male. Heterozygosity increased slightly to 0.51 during that period (C. Quinn, UC Davis, unpublished data), but still remained well below the population's historical heterozygosity level (0.63) and that of other, larger red fox populations (e.g., Sacramento Valley red foxes [0.64], San Joaquin Valley red foxes [0.69], Rocky Mountain red foxes [0.73]; Sacks et al. 2010a). No other immigrants have subsequently been detected in the Lassen study area.

An estimate of potential SNRF abundance in the Lassen population, given current habitat and climatic conditions, will be forthcoming in Green et al. (in preparation).

## II.D.1.3. STUDY EFFORTS

Contemporary study of the Lassen SNRF population is summarized in Figure 42.

## II.D.1.4. SUMMARY

Numerous lines of evidence (e.g., lack of detections in portions of the historical range, few individuals

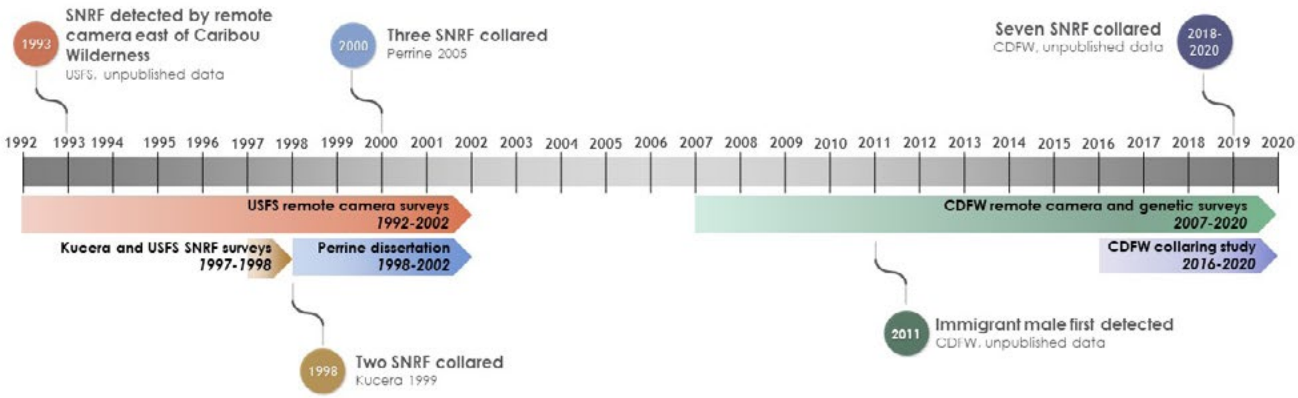


Figure 42. Timeline of study efforts and salient findings in the Lassen population, 1992–2020.

detected, high genetic distances to other red fox populations, low heterozygosity, small genetic effective population size, limited observed reproduction, and documented breeding between full siblings) indicate that the Lassen population is very small, isolated, and inbred, with low genetic diversity and a distribution greatly reduced from its historical extent. Without an influx of novel genetic material, the Lassen population may become extirpated within a small number of generations.

## II.D.2. CURRENT POPULATION STATUS: SIERRA NEVADA

### II.D.2.1. DISTRIBUTION

According to Grinnell et al. (1937:381), SNRF in the Sierra Nevada were once distributed "continuously or very nearly so" from Monache Meadows in Kern County to Sierra County north of Lake Tahoe. Most detections were at elevations above 2,130 m, and "population centers" were located near Mono Lake and Mt. Whitney (Grinnell et al. 1937:381). Observations from Piute Mountain in Kern County (Grinnell et al. 1937) and Yosemite Valley (Schempf and White 1977) lie at the margins of this historical range, and may represent red foxes of other lineages or subspecies.

Once believed extirpated from the Sierra Nevada by the 1990s, SNRF were rediscovered in 2010 during remote camera surveys conducted by USFS near Sonora Pass, north of YNP in California (Statham et al. 2012b; Quinn et al. 2019). During 2010–2020, the greatest number of individuals was detected in the Sonora Pass study area. At least 4 individual SNRF were detected in northern YNP, adjacent to the Sonora Pass study area, during 2015–2020 (NPS, unpublished data). Since 2018, detections beyond the Sonora Pass and YNP study areas have raised the possibility that the contemporary distribution of SNRF in the Sierra Nevada is more broad than previously thought, or has expanded recently (Figure 4). During 2018–2020, a minimum of 3 SNRF (1 male and 2 females) were detected in the Mono Creek study area northwest of Bishop, California. The male was previously sampled in September 2017 near Sonora Pass, demonstrating a dispersal of approximately 120 km (Figure 40; Hatfield et al. 2020; C. Quinn, UC Davis, unpublished data).

Additional sparse detections of SNRF have occurred in other areas of the Sierra Nevada, but no DNA samples have been collected from these areas to enable genetic identification. In June 2019, at least 1 SNRF was photographed by remote cameras in the Ritter Range study area, approximately 40 km north of the Mono Creek study area and less than 20 km south of the southernmost detection in YNP. In July 2019 and March 2020, SNRF were photographed by 2 remote cameras on the

Sierra crest near Mammoth Lakes, California, approximately 25 km north of Mono Creek and 15 km south of the Ritter Range detections (Hatfield et al. 2020). In October 2019, a SNRF was photographed by a remote camera in YNP approximately 5 km south of Highway 120 (NPS, unpublished data). In August 2020, a SNRF was photographed by a visitor near Carson Pass on Highway 88, approximately 20 km north of the northernmost previous SNRF detections near Ebbetts Pass on Highway 4.

It is unknown whether these recent detections represent additional dispersal events from the Sonora Pass study area, descendants of such dispersers, or the presence of a remnant population of SNRF in these areas. Based on these detections, the distribution of the contemporary Sierra Nevada population appears to be roughly continuous along the Sierra crest at elevations above 2,750 m between Highway 88 and the Mono Creek watershed (Stock and Eyes 2017; Quinn et al. 2019; Hatfield et al. 2020; NPS, unpublished data).

## II.D.2.2. DEMOGRAPHICS AND GENETICS

The Sierra Nevada population has changed considerably since its rediscovery in 2010 due to the immigration of several unrelated red foxes into the Sonora Pass study area. Prior to 2012, the Sierra Nevada population was thought to be restricted to this study area and appeared to be very small, isolated, and inbred. During 2010–2012, 8 individual SNRF (6 females, 2 males) were documented in the Sonora Pass study area. All possessed a mitochondrial haplotype previously detected only in the historical SNRF population (Statham et al. 2012b), and nuclear genetic assignment tests supported the hypothesis that these individuals represented a remnant of the historical population. These individuals also shared no haplotypes with neighboring contemporary populations (specifically, Lassen, Great Basin, Sacramento Valley, and lowland California red foxes), suggesting historical isolation (Quinn et al. 2019).

This small, isolated remnant population exhibited a low level of genetic diversity consistent with inbreeding. Quinn et al. (2019) estimated the genetic effective population size at 6.1 (95% CI 2.6-15.6) and the heterozygosity at 0.43 (SD = 0.04), a one-third decline from the historical heterozygosity of 0.64 (Sacks et al. 2010a). Mitochondrial diversity also declined from 8 haplotypes in the historical population to a single haplotype among contemporary samples. Researchers detected no evidence of reproduction in the population from 2010–2012, potentially as a result of inbreeding depression.

In 2012, 2 unrelated male red foxes were detected in the population for the first time from DNA in scat samples. Both individuals assigned most closely to a reference population in eastern Nevada and were presumed to be first-generation immigrants. We refer to these immigrants as Great Basin red foxes because of their likely geographic origins; their genetic history involves admixture from Rocky Mountain, eastern (i.e., likely via fur farm), and possibly boreal red fox lineages. After this initial immigration event, Quinn et al. (2019) detected 7 offspring from 2 litters produced by native-immigrant pairs in 2013, and confirmed that all reproduction that year was between resident native females and immigrant males. In subsequent years reproductive output continued at similar levels, producing F1 and F2 hybrids and backcrosses with no evidence of reproduction between native animals. This increase in reproductive output following immigration provides additional support for inbreeding depression as a mechanism limiting population growth prior to 2012 (Quinn et al. 2019).

At least 2 more immigration events have occurred since 2012: a cluster of 5 closely-related Great Basin individuals (4 males, 1 female; see Quinn et al. 2019) first sampled in the study area in 2014–2015, and an additional unrelated Great Basin male in 2017. During 2015–2017, the heterozygosity of the admixed population increased to 0.64 (SD = 0.03, n = 19), similar to the heterozygosity level estimated in the historical population based on genetic analysis of museum specimens (Sacks et al. 2010a; Quinn et al. 2019).

Abundance estimates increased during the study period, suggesting population growth following the infusion of genetic variation. A total of 47 individual SNRF were detected during 2010–2019, and the minimum population size in 2019 was 15 individuals. Adult survival was estimated at 0.70, considerably higher than that reported in other red fox populations. This suggests that population growth prior to immigration was more likely limited by reproduction or recruitment than by adult survival. While density estimates remained stable throughout the study period at about 4 foxes per 100 km2, the geographic distribution of samples increased. All samples found at the periphery of the study area or beyond its boundaries assigned to hybrid individuals with ancestry immediately traceable to individuals from the focal study area, indicating a possible range expansion subsequent to outbreeding (Quinn et al. 2019).

An estimate of potential SNRF abundance in the Sierra Nevada population, given current habitat and climatic conditions, will be forthcoming in Green et al. (in preparation).

## II.D.2.3. STUDY EFFORTS

Contemporary study of the Sierra Nevada population is summarized in Figure 43.

## II.D.2.4. SUMMARY

Once distributed along the entire Sierra crest, the Sierra Nevada population apparently declined in recent decades to a small number of individuals inhabiting the Sonora Pass study area. This population was highly isolated and inbred until several immigrant red foxes from a Great Basin population entered the study area beginning in 2012. Since then, the Sierra Nevada population has increased in abundance and genetic diversity, suggesting a release from inbreeding depression, at least in the short term. The population also seems to have expanded its range, with a likely continuous distribution between Highway 88 and the Mono

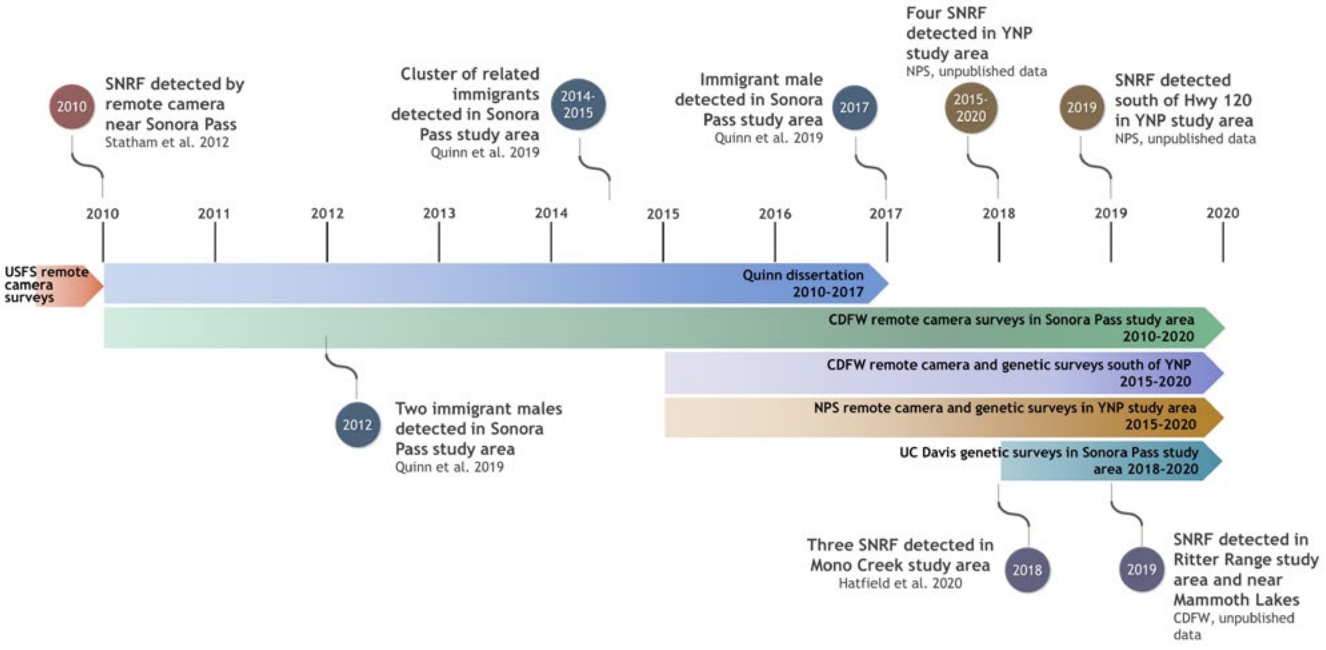


Figure 43. Timeline of study efforts and salient findings in the Sierra Nevada population, 2010–2020.

Creek study area. At least 1 individual is known to have dispersed from the Sonora Pass study area to the Mono Creek study area; the identity of other individuals detected south of Highway 120 and north of Highway 4 is unknown. Large areas of the historical range in the Sierra Nevada have not been surveyed for SNRF (Figure 4; Figure 20); it is possible that additional dispersers or remnant populations exist undetected in these areas.

## II.D.3. CURRENT POPULATION STATUS: OREGON

### II.D.3.1. HISTORICAL ORIGINS AND DISTRIBUTION

Two subspecies of red fox are known to be native to Oregon: Rocky Mountain red foxes in the Blue and Wallowa Mountains in the northeastern part of the state, and SNRF in the Cascades. The latter were initially presumed to be members of the Cascade subspecies, but more recent genetic analyses confirmed their genetic distance from Cascade red foxes in Washington and close relatedness to SNRF in the Sierra Nevada and Lassen populations (Bailey 1936; Verts and Carraway 1998; Aubry 1983; Sacks et al. 2010a). Historical accounts and museum specimens suggest that montane red foxes (now considered SNRF) were found typically in the higher elevations of the Oregon Cascades, and were absent from or rare in lower elevation areas west and east of the Cascades crest (Figure 16; Bailey 1936; Aubry 1983).

In addition to these montane populations, historical records document red foxes inhabiting the Willamette Valley west of the Cascades beginning in the 1940s (Bailey 1936; Verts and Carraway 1998; Aubry 1983). While the exact provenance of these lower elevation red foxes is uncertain, it is presumed that they were originally introduced from the eastern U.S. for fur farming (Aubry 1983). Similarly, red foxes have been reported with increasing frequency since the 1970s in lower elevations east of the Cascades, from the western foothills of the Blue Mountains, across farmlands in the Columbia River Plateau, Snake River Plains, and Deschutes River Valley, and through developed areas up to the base and possibly even into the eastern foothills of the Cascades, less than 35 km from the SNRF's historical range along the Cascades crest (Verts and Carraway 1998; Green et al. 2017; ODFW, unpublished data). Assignment analyses of genetic samples from these areas indicate that the ancestry of this admixed population can be attributed in part to the native Rocky Mountain subspecies in northeastern Oregon, with additional contributions likely from eastern and/or boreal lineages, perhaps via fur farms (Quinn et al. in review).

In summary, Oregon contains multiple populations of red foxes derived from multiple lineages. The SNRF is one of 2 montane subspecies native to the state, with a putative historical distribution that extended along the crest of the Cascades as far north as the Columbia River.

### II.D.3.2. CONTEMPORARY DISTRIBUTION, ABUNDANCE, AND SURVEY EFFORTS

Contemporary detections of SNRF in Oregon are distributed along the north-south axis of the historical range in the higher elevations of the Cascades (Figure 5; Hiller et al. 2015; McFadden-Hiller and Hiller 2015; Quinn et al. 2018; J. Akins, Cascades Carnivore Project, unpublished data; ODFW, unpublished data; NPS, unpublished data), with some observations east of the Cascades crest at lower elevations than those of historical records (ODFW, unpublished data). Within this range, recent SNRF detections occur in 3 geographically distinct clusters, which we refer to as the Mt. Hood, Central Cascades, and CLNP study areas. Apparent gaps in this distribution—in particular, that between the Central Cascades and CLNP study areas—may indicate either absence of SNRF or simply a lack of sampling effort in those areas. Distribution models suggest habitat is continuous between the Central Cascades and CLNP, whereas the gap separating detections in the Central Cascades from those near Mt. Hood corresponds to a gap in SNRF habitat (Quinn et al 2018; Green et al, in preparation; Stermer, in preparation). Moreover, genetic analyses indicate high connectivity between the Central Cascades and CLNP, but isolation of Mt. Hood from the Central Cascades (Quinn et al. in review).

Levels of survey intensity and methods employed for research and monitoring have varied by study area (Figure 44). Early efforts were primarily designed to determine presence of SNRF. As a result, quantitative abundance or density estimates are not available currently for SNRF in the Oregon Cascades; however, an estimate of potential SNRF abundance in this population, given current habitat and climatic conditions, will be forthcoming in Green et al. (in preparation).

### II.D.3.2.1. MT. HOOD STUDY AREA

To date, the only research conducted in the Mt. Hood study area involved periodic camera trapping, scat collections for genetic analysis, and track surveys around the base of the Mt. Hood massif (Figure 5; J. Akins, Cascades Carnivore Project, unpublished data; Cascadia Wild, unpublished data). Estimates of abundance using current datasets from this study area would be limited by the sparseness of detections and limited intensity of survey efforts to date.

### II.D.3.2.2. CENTRAL CASCADES STUDY AREA

In the Central Cascades study area, SNRF have been studied since 2012 using remote cameras, hair snares, scat collection, and GPS collars (Hiller et al. 2015; McFadden-Hiller and Hiller 2015; ODFW, unpublished data, USFS, unpublished data; Wildlife Ecology Institute, unpublished data). A total of 9 genetically confirmed SNRF were collared during 2017–2018. Most SNRF were captured within or near recreational areas (e.g., snow parks, ski resorts) and are assumed to have been habituated to humans through food conditioning.

Noninvasive detections of SNRF in the Central Cascades study area extend approximately 115 linear km from Mt. Jefferson in the north to Diamond Peak and Willamette Pass in the south (Figure 5). While population estimates are not available currently, this broad distribution could suggest that SNRF are more abundant in the Central Cascades than in other SNRF study areas, though population sizes may still be small relative to other red fox subspecies. The greatest concentrations of detections are in the vicinity of the Three Sisters and Mt. Bachelor, where ODFW conducted a recent multi-year telemetry study, and near Willamette Peak, where the Deschutes National Forest has conducted repeated scat surveys since 2014. It is unclear whether the increased number of detections at these sites reflect higher abundance or greater sampling effort relative to other study areas.

### II.D.3.2.3. CLNP STUDY AREA

In the CLNP study area, the SNRF population is likely very small and may be declining based on remote camera surveys, scat collection, and observations from park staff and visitors. During 1932–1950, red foxes (presumably SNRF) were observed annually in CLNP, and park staff developed crude abundance estimates based on these observations ranging from 10 to 50 individuals (Unknown Author 1932; Simpson 1933; Evans 1933; Evans 1934; Unknown Author 1935; Unknown Author 1936; Unknown Author 1937; Frost 1938; Frost 1939; Frost 1940; Frost 1941; Frost 1942; Leavitt 1944; Leavitt 1945; Crouch 1946; Parker 1947; Unknown Author 1948; Huestis 1949; Unknown Author 1950). In 2012, SNRF were detected at 7 of 42 remote camera stations in the park (Immel 2013). In 2013, a SNRF was

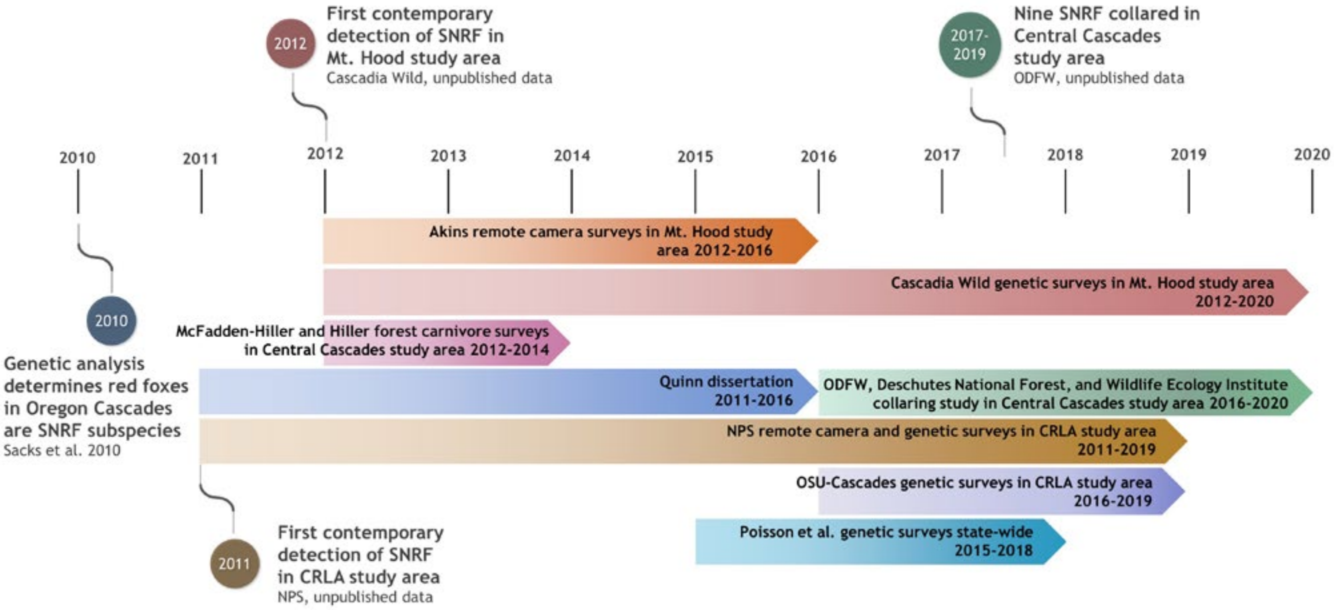


Figure 44. Timeline of study efforts and salient findings in Oregon, 2010–2020.

documented in only 1 location at an elevation of 2,240 m, one of the highest sites sampled that year (Hansen et al 2013). During 2014–2018, despite numerous remote cameras deployed each year throughout the entire park, only 1 SNRF was documented in the Rim Village area on the southwest side of Crater Lake. In 2020, SNRF were photographed at 5 remote camera stations where they had been detected in previous years; it was not possible to tell whether multiple individuals were present (Figure 5).

Concurrent with remote camera surveys, park staff and visitors were encouraged to submit observations and photographs of red foxes. During 2013–2015, 110 observations of red foxes were reported, 36 of these accompanied by photographs (Figure 45). Since 2015, only 7 observations were reported, none of which included photographs.

During 2012–2015, of 29 genetic samples (10 hair, 1 muscle tissue, and 18 scat) submitted to UC Davis for analysis, 6 were determined to be SNRF and no other red fox subspecies were detected. During 2016–2019, in collaboration with Oregon State University - Cascades, student interns and

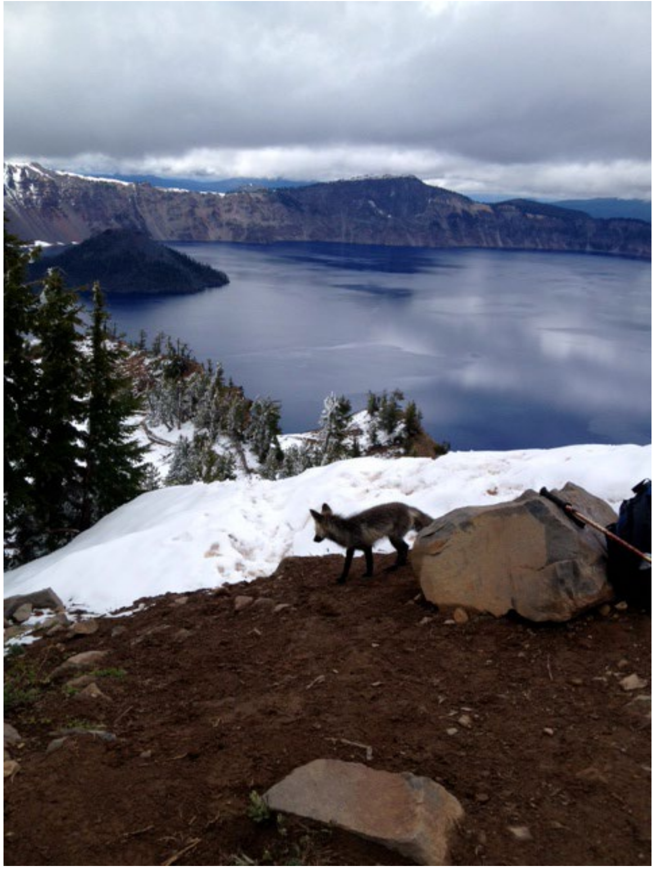


Figure 45. SNRF in CLNP, 2013. Photo courtesy of Emily Prudhomme and Sean Mohren.

volunteers conducted more intensive scat surveys in areas of CLNP where SNRF were known to occur, collecting 128 scat samples of which only 3 were genetically classified as SNRF with no other red fox subspecies detected (Schenk 2015; Gumtow-Farrior and Gumtow-Farrior 2017; Gumtow-Farrior and Gumtow-Farrior 2018).

SNRF detections in CLNP are located approximately 280 km north of the Lassen population in California, and approximately 150 km south of the nearest known detections in Oregon, in the southern portion of the Central Cascades study area on the Deschutes National Forest (Figure 1). However, large areas of these potential gaps in distribution have not been surveyed for SNRF.

## II.D.3.3. CONTEMPORARY GENETICS

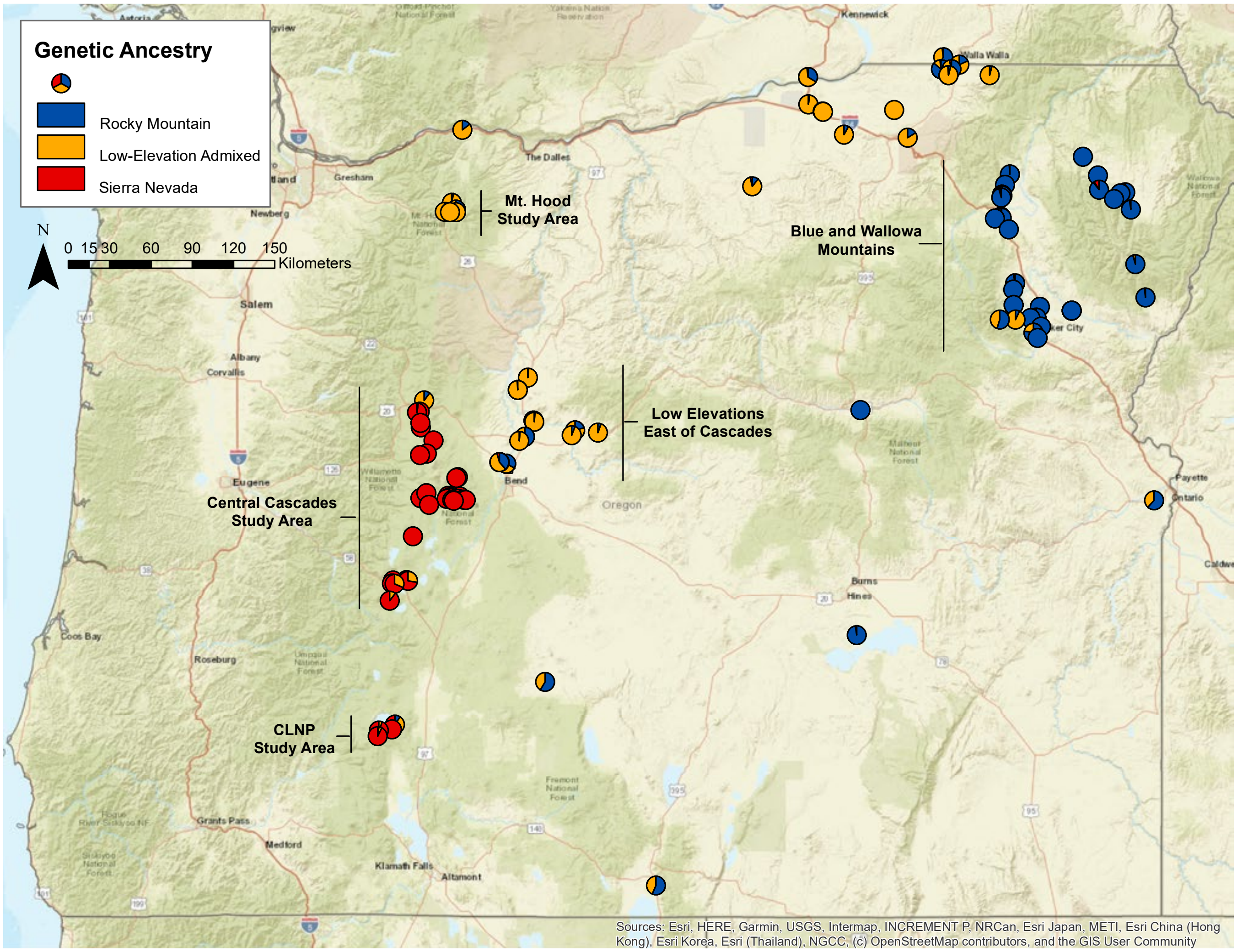
The majority of genetic samples collected within the Oregon Cascades since 2010 were genetically distinct from all other samples collected within Oregon, consistent with the expectation that SNRF have been relatively isolated from other red fox populations in Oregon, and similar to the genetic histories of SNRF populations in California. Samples exhibited low heterozygosity (0.55) and a small genetic effective population size (Ne = 9, 95% CI 4–13), suggesting that SNRF in Oregon have experienced a bottleneck in the past, though not as severe as bottlenecks experienced by SNRF populations in California (Quinn et al. in review). In particular, the small effective population size raises the possibility that SNRF in Oregon could be vulnerable to genetic drift and inbreeding depression, although field data from the Central Cascades study area do not suggest impaired fitness to date.

A small number of individuals sampled in the Oregon Cascades showed signs of admixture with lower elevation red fox populations east of the Cascades (Figure 46). Most notably, individuals sampled within the Mt. Hood study area had a high degree of admixture and were genetically differentiated from other SNRF, based on analyses using microsatellite, mitochondrial, and Y-chromosome markers (Quinn et al. in review). Despite their proximity to lower elevation populations east of the Cascades, only 2 individuals from the Central Cascades study area and 1 individual from the CLNP study area contained admixture from these lower elevation populations. One individual from the Central Cascades study area appeared to be a non-SNRF immigrant (Quinn et al. in review).

## II.D.3.4. SUMMARY

SNRF seem to persist throughout much of their historical range in the Oregon Cascades, with some gaps in distribution that likely indicate absence, and others that potentially indicate a lack of sampling effort. Due to insufficient data, the degree of connectivity between SNRF in the Central Cascades and CLNP study areas is unknown. Contemporary population size has not been estimated in any study area; however, SNRF may be more broadly distributed in the Central Cascades than in other study areas, perhaps as a result of greater abundance or greater sampling intensity. We have no information about abundance in the Mt. Hood study area. In the CLNP study area, sampling efforts since 2012 suggest the population is very small and may be declining in abundance.

Most SNRF in Oregon are genetically distinct from other red foxes in the state, but some individuals, particularly in the Mt. Hood study area, show evidence of genetic introgression from admixed red fox populations east of the Cascades. While the extent of gene flow into the Cascades appears limited at present, the cause, origin, and rate of this gene flow into the SNRF population are not well understood.



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Figure 46. Program Structure analysis showing genetic ancestry of red fox samples in Oregon (Quinn 2018).

# III. STRATEGY

## III.A. POTENTIAL THREATS

It is difficult to assign specific causes to the historical decline of SNRF populations. Reasonable hypotheses include unregulated harvest, exposure to poisons used for predator control near grazing operations, and infectious disease. Reduced population sizes likely led to genetic drift and an accumulation of loci with fixed deleterious recessive alleles, resulting in inbreeding depression, which kept populations small even after hunting and trapping of red foxes ceased in California and predator control practices became less widespread (Perrine et al. 2010; USFWS 2015b, 2018; Quinn et al. 2019). Populations of SNRF in California were thought to occur at low densities even in the 1920s and 1930s (Grinnell et al. 1937).

Our understanding of the contemporary threats affecting SNRF populations is limited, and this fundamental uncertainty makes it difficult to rank threats by severity or urgency. Instead, we loosely order potential threats according to our level of confidence that the threat is negatively affecting SNRF populations at present or is likely to have negative effects if it occurs in the future. We discuss our current understanding of each potential threat and its effects, and identify remaining uncertainties. Where no evidence is currently available to directly assess whether a particular threat affects SNRF or is likely to do so in the future, we acknowledge that data deficiency and present reasonable science-based opinion about the nature and potential consequences of the threat.

For very small populations, there may be no practical difference between individual and population-level impacts. Therefore, we consider the potential population-level consequences of each threat, even those that are only known or expected to affect a small number of individuals.

We enumerate possible next steps for research or management of potential threats in section III.B. Information Needs and section III.C. Management Actions.

## III.A.1. SMALL POPULATION SIZE AND HISTORICAL ISOLATION

Small population size and isolation render populations vulnerable to numerous potential stressors including inbreeding depression, loss of adaptive potential, genetic swamping, disease, demographic and environmental stochasticity, and catastrophic events (Franklin 1980; Soulé 1980; Gilpin 1987; O'Brien 2003). Very small populations can be extirpated by chance events that kill multiple individuals (Gilpin 1987). When small populations are also isolated, limited gene flow and genetic drift can result in loss of adaptive potential and the accumulation of loci fixed for deleterious recessive alleles, which can decrease fitness in a population by reducing reproductive success and survival (Soulé 1980).

We know of only 3 extant populations of SNRF, which appear to occupy only portions of their historical range (Perrine et al. 2010; Sacks et al. 2010a; Statham et al 2012; USFWS 2015b, 2018; Quinn et al 2019; Quinn et al. in review). Genetic analyses suggest that there is no connectivity among populations and that each population has experienced a bottleneck, resulting in small genetic effective population sizes (Quinn et al. 2019; Quinn et al. in review). Detailed information about distribution, minimum population size estimates, genetic diversity, and genetic connectivity of each population is presented in section II.D. Current Status of Known Populations and summarized below.

We do not know how recent immigration events into SNRF populations will affect long-term population growth, nor have we estimated the carrying capacities of SNRF habitat in different regions. We acknowledge that unknown ecological factors, perhaps including some of the potential threats described in this Strategy, may contribute to limiting SNRF population size in the future. Nevertheless, we conclude that small population size and historical isolation are in and of themselves the primary confirmed threats currently impacting many SNRF populations. These factors are also important considerations in our assessment of other potential threats discussed below.

### III.A.1.1. LASSEN

The Lassen population is extremely small, likely comprising fewer than 30 individuals. During 13 years (2007–2019) of surveys, a total of 36 individuals were identified from genetic samples collected in the study area, with no more than 10 individuals detected in any calendar year (CDFW, unpublished data; C. Quinn, UC Davis, unpublished data). Occupied habitat in the Lassen Peak region is separated geographically from any other known SNRF populations by at least 270 linear km. Available habitat is also spatially constrained (Green et al. in preparation; Stermer et al. in preparation), making the population highly vulnerable to localized environmental stochasticity. Analysis of genetic structure shows that Lassen samples have high genetic distances to all other red fox populations, indicating very minimal genetic connectivity (Quinn et al. in review).

Reproduction in this population also appears to be very low. The available evidence suggests that litters are small and infrequent, with only 1 litter documented per year in 1999, 2018, and 2019, and litter sizes ranging from 1–3 pups (Perrine 2005; CDFW, unpublished data). The population is also inbred: both recent litters were produced by sibling pairs, and all individuals genetically identified during 2016–2019 were descendants of a single immigrant male that entered the population in 2011 (CDFW, unpublished data; C. Quinn, UC Davis, unpublished data). Consistent with its small size, isolation, and inbreeding, the population has low genetic diversity: heterozygosity after the 2011 immigration event was 0.51, and the genetic effective population size of native individuals was estimated at 3 (95% CI 2–5; Quinn et al. in review).

In short, multiple lines of geographic, demographic, and genetic evidence support the conclusion that the Lassen population is threatened by small population size, limited distribution, and isolation.

### III.A.1.2. SIERRA NEVADA

Since the immigration of several Great Basin red foxes into the Sierra Nevada population during 2012–2017, reproductive rates and minimum abundance estimates have increased, suggesting a release from inbreeding depression and subsequent population growth (Quinn et al. 2019). The geographic distribution of detections has also increased, indicating a possible range expansion (Stock and Eyes 2017; Quinn et al. 2019; Hatfield et al. 2020; CDFW, unpublished data; NPS, unpublished data), though large areas of historical range in the Sierra Nevada have not been surveyed for SNRF. It is unknown whether immigration from the Great Basin continues, what its long-term effects will be, or whether the Sierra Nevada population will continue to grow.

Notwithstanding recent growth, the Sierra Nevada population is still very small. Forty-seven individual SNRF were detected over a decade of study from 2010–2019. The minimum population size was estimated at 18 individuals in 2017 (Quinn et al. 2019) and 15 individuals in 2019 (C. Quinn, UC Davis, unpublished data), with post-immigration heterozygosity estimated at 0.64 (Quinn et al. 2019). Despite recent connectivity with a Great Basin population, Sierra Nevada SNRF also remain highly isolated from other SNRF populations (Quinn et al. 2019). The nearest SNRF population is approximately 250 km north in the Lassen Peak region, and habitat analyses suggest limited potential for connectivity between the two populations (Cleve et al. 2011; Spencer and Rustigian-Romsos 2012; Green et al. in preparation; Stermer in preparation).

### III.A.1.3. OREGON

SNRF have been detected in 3 study areas in Oregon: Mt. Hood, Central Cascades, and CLNP. It is unknown whether SNRF in Oregon are best characterized as a two or three independent populations. Although no abundance estimates are available currently for these study areas, SNRF seem to be distributed more broadly in the Central Cascades study area than in the CLNP study area, though populations in both study areas may be small. The population in the CLNP study area is likely extremely small given the scarcity of recent photographic and scat detections. Sampling effort in the Mt. Hood study area is not currently sufficient to enable assumptions about population size there.

Genetic analysis revealed substantial admixture from non-SNRF sources in the Mt. Hood study area, which was isolated from the Central Cascade and CLNP study areas (Quinn et al. in review). Conversely, genetic samples from the rest of the Cascades were indicative of an isolated population with low heterozygosity (0.55) and a small genetic effective population size (9, 95% CI 4–17), suggesting a past bottleneck and the potential for genetic drift and inbreeding depression.

## III.A.2. VEHICLE STRIKES

Vehicle strikes are one of the only known contemporary causes of mortality for SNRF. One SNRF was killed by a vehicle on Highway 108 near the Sonora Pass study area in 2011 (Statham et al. 2012b); this highway is closed during the winter but heavily used during the rest of the year. Highway 120 through YNP, also closed during the winter, experiences considerable traffic when it is open (an average of approximately 200,000 vehicles one-way per year since 1985; NPS, unpublished data) and passes within 5 km of a remote camera that detected a SNRF in 2019. SNRF detections in the Mono Creek and Ritter Range study areas were in remote roadless wilderness, although seasonally open roads exist within approximately 2–10 km of each detection.

Since 2017, 5 SNRF—3 pups, 1 adult, and 1 individual of unknown age—have been killed by vehicle strikes along the Cascade Lakes Highway in the vicinity of Mt. Bachelor in the Central Cascades study area of Oregon. The portion of the Cascade Lakes Highway where these vehicle strikes have occurred is open year-round. Several additional carcasses have been found or reported near roads in the Mt. Bachelor area and farther south near Gilchrist. Den sites located near roadways in the Mt. Bachelor area increase the risk of vehicle strikes killing juvenile SNRF. A growing level of human activity at Mt. Bachelor may have led to SNRF habituation, which could increase the likelihood of vehicle strikes (J. Bowles, ODFW, personal communication 2019). One SNRF was killed by a vehicle in CLNP in July 2013 on Munson Valley Road, which is typically open year-round (S. Mohren, NPS, personal communication 2019); during that month, NPS estimates 24,597 vehicles traveled the road one-way (NPS, unpublished data).

We do not know the number of additional vehicle strikes of SNRF that occur undetected in California or Oregon, or the severity of this threat for SNRF populations. Nonetheless, vehicle strikes are the most prevalent cause of mortality for SNRF identified to date, and in very small populations, even the loss of a few individuals to vehicle strikes may constitute a population-level threat.

## III.A.3. RODENTICIDES

In 2011, bromadiolone, a second-generation anticoagulant rodenticide (AR), was detected in a liver sample from a SNRF killed by vehicle strike near Sonora Pass. In 2019, a GPS-collared red fox found dead within historical SNRF range in the Central Cascades study area in Oregon may have died from AR intoxication. The fox was exposed to 2 second-generation ARs, bromadiolone and brodifacoum. Although the concentration of brodifacoum detected in liver tissue was well above thresholds considered toxic for domestic dogs, tissue autolysis precluded confirmation of clinical signs of toxicity (J. Burco, ODFW, and D. Clifford, CDFW, personal communications 2020).

Exposure to one or more ARs is frequently detected in carnivore carcasses submitted to CDFW (D. Clifford, CDFW Wildlife Investigations Lab, personal communication 2019). AR intoxication and exposure have been well-documented in monitored populations of fishers (Gabriel et al. 2012, 2015) and mountain lions (Riley et al. 2007; Rudd et al. 2018) in California. Privately owned or leased resorts and cabins exist in SNRF habitat in both Oregon and California, presenting potential avenues for rodenticide exposure. Rodenticides may also be used on small areas of private land that occur within SNRF habitat.
Cannabis cultivation sites have emerged as a common source of rodenticide contamination in the environment (Gabriel 2012, 2015). During 2010–2018, 30% of public land cannabis cultivation complexes (PLCCCs) detected in California—over 155 sites—were in the Sierra Nevada at elevations

ranging from 1,500 m to 3,400 m, with a median elevation of 1,716 m. This estimate should be considered a minimum, as many PLCCCs likely go undetected. Although only 25% of known PLCCCs occur above 2,000 m, the elevational range of documented sites overlaps with the elevational range of survey cells occupied by SNRF (2,607 m–3,651 m), suggesting that the existence of PLCCCs within SNRF habitat is possible.

Only 10–25% of all known cultivation sites detected in California on public lands are reclaimed. Therefore, 75–90% of PLCCC locations contain cultivation infrastructure and hazardous materials, and pesticides are likely still present and intact in these areas (Gabriel and Wengert in preparation). Although no cannabis cultivation sites are documented within occupied SNRF habitat, given the prevalence of PLCCCs in montane zones of the Sierra Nevada, it is possible that these sites occur in areas used by SNRF. We do not have information about PLCCCs within areas occupied by SNRF in Oregon.

## III.A.4. IMMIGRATION AND INTROGRESSION

Each extant SNRF population has experienced some level of recent genetic introgression from non-SNRF immigrants. We recognize that admixture between previously isolated populations can be an important and constructive evolutionary process, and that positive aspects, such as genetic rescue from inbreeding depression, must be assessed and weighed against the risks. In this threats assessment, however, we specifically address the potential for negative consequences from immigration and introgression.

Swamping by immigrant genes could result in total genomic replacement and a loss of local adaptations critical to SNRF persistence in the long term. Outbreeding with immigrant foxes could cause depressed fitness in admixed offspring due to the displacement of locally adaptive alleles. Gene flow from large and recently admixed populations, such as those in the Great Basin and central Oregon east of the Cascades, may also introduce new deleterious recessive alleles, which could increase to fixation due to either drift or variance in reproductive success, such as when a few immigrants are successful and their progeny are disproportionately represented in future generations. The addition of new deleterious recessive alleles can intensify inbreeding depression if the effective population size remains small and inbreeding returns (Hedrick and Frederickson 2010; Bijlsma et al. 2010; Hedrick et al. 2014). Possible non-genetic consequences of immigration include competition with or displacement of native individuals, reduction of prey populations, transmission of maladaptive behaviors through social learning, or the introduction of disease.

The long-term consequences of gene flow between SNRF and other red fox populations are unknown. Numerous factors influence the probability and severity of inbreeding and outbreeding depression, such as the capacity for SNRF populations to increase to large sizes, the rate of immigration relative to the size of SNRF populations, and the degree of adaptive differentiation between native and immigrant populations.

### III.A.4.1. LASSEN

An immigrant male—itself a hybrid between a Sacramento Valley red fox and an eastern red fox (possibly derived from fur farm stock)—was first documented in the Lassen population in 2011. It subsequently bred with a native female, producing at least 2 offspring which then bred with native individuals. This immigration seems to have been a single, rare event. Nonetheless, its impact appears to be significant, as all individual foxes in the population genotyped between 2016–2019 were descendants of the immigrant male. Although most alleles in these individuals are native due to backcrossing (Figure 47), the small size of the Lassen population makes it susceptible to swamping from even relatively low rates of future immigration.

### III.A.4.2. SIERRA NEVADA

The SNRF population in the Sonora Pass study area is admixed with red foxes that apparently immigrated on multiple occasions from a Great Basin population (Figure 48), which contains Rocky Mountain ancestry with admixture from eastern North American and potentially boreal red fox lineages. The immediate demographic impacts of this introgression appear to have been beneficial, triggering increased reproduction and an expanded distribution, but the long-term fitness effects are unknown, as are the rate and trend of immigration from the Great Basin population (Quinn et al. 2019).

### III.A.4.3. OREGON

Samples from the majority of the Oregon Cascades, from Mt. Jefferson to CLNP, suggest a SNRF population with very limited introgression from outside populations to date. Genetic samples of SNRF from the Mt. Hood study area, however, show substantial admixture, indicating a high degree of connectivity with a red fox population occupying lower elevations of central Oregon east of the Cascades (Figure 46; Quinn et al. in review). Based on genetic samples collected north of Bend in the vicinity of Tumalo and Redmond, this lower elevation population extends to the eastern slope of the Cascades, less than 35 km from the Cascades crest where SNRF have been sampled (Quinn et al. in review). Given their proximity, the potential for gene flow is high between this population and previously isolated SNRF in the Cascades. However, connectivity may be at least partially inhibited by habitat gradients, mate preference, and other factors (e.g., Sacks et al. 2011; Merson et al. 2017; Cross et al. 2018).

## III.A.5. CLIMATE CHANGE

SNRF appear to be restricted to montane, subalpine, and alpine habitats, though we do not fully understand the mechanisms constraining their distribution, and specific habitat associations vary by region. Models of potential montane red fox distribution have consistently found climatic variables and land cover types to be strong predictors of red fox occurrence (e.g., Cleve et al. 2011; Akins 2017; Quinn et al. 2018; Green et al. in preparation; Stermer in preparation). Rising temperatures and diminished snowpacks will likely change the vegetation composition of SNRF habitats, but the degree to which these changes pose a threat to SNRF conservation is unknown, as is the subspecies' capacity to adapt to changing habitat conditions. The effects of climate change may be more significant in areas where suitable habitat is already limited in spatial extent (e.g., Lassen), and where SNRF are already utilizing the highest areas available (e.g., Mt. Hood).

Climate change may also impact SNRF prey or competitors. Changes in precipitation and temperature, and associated snow cover loss and vegetation changes, may affect habitat suitability for small mammal species and could drive range shifts or reductions, though the effects of climate change on small mammal range limits are uncertain and variable (Moritz et al. 2008; Morelli et al. 2012; Gibson-Reinemer and Rahel 2015; Rowe et al. 2015; Santos et al. 2017). Diminished snowpacks may also facilitate increased use of SNRF habitat by other carnivore species, including gray foxes and coyotes (e.g., Cross 2015; Tucker et al. 2019), that may compete with SNRF for prey (Sargeant et al. 1987; Cypher 1993; Gosselink et al. 2003; Dodd and Whidden 2018).

## III.A.6. COMPETITION

Numerous carnivore species, such as coyotes, martens, gray foxes, bobcats, and fishers, co-occur with SNRF and may compete with them for prey

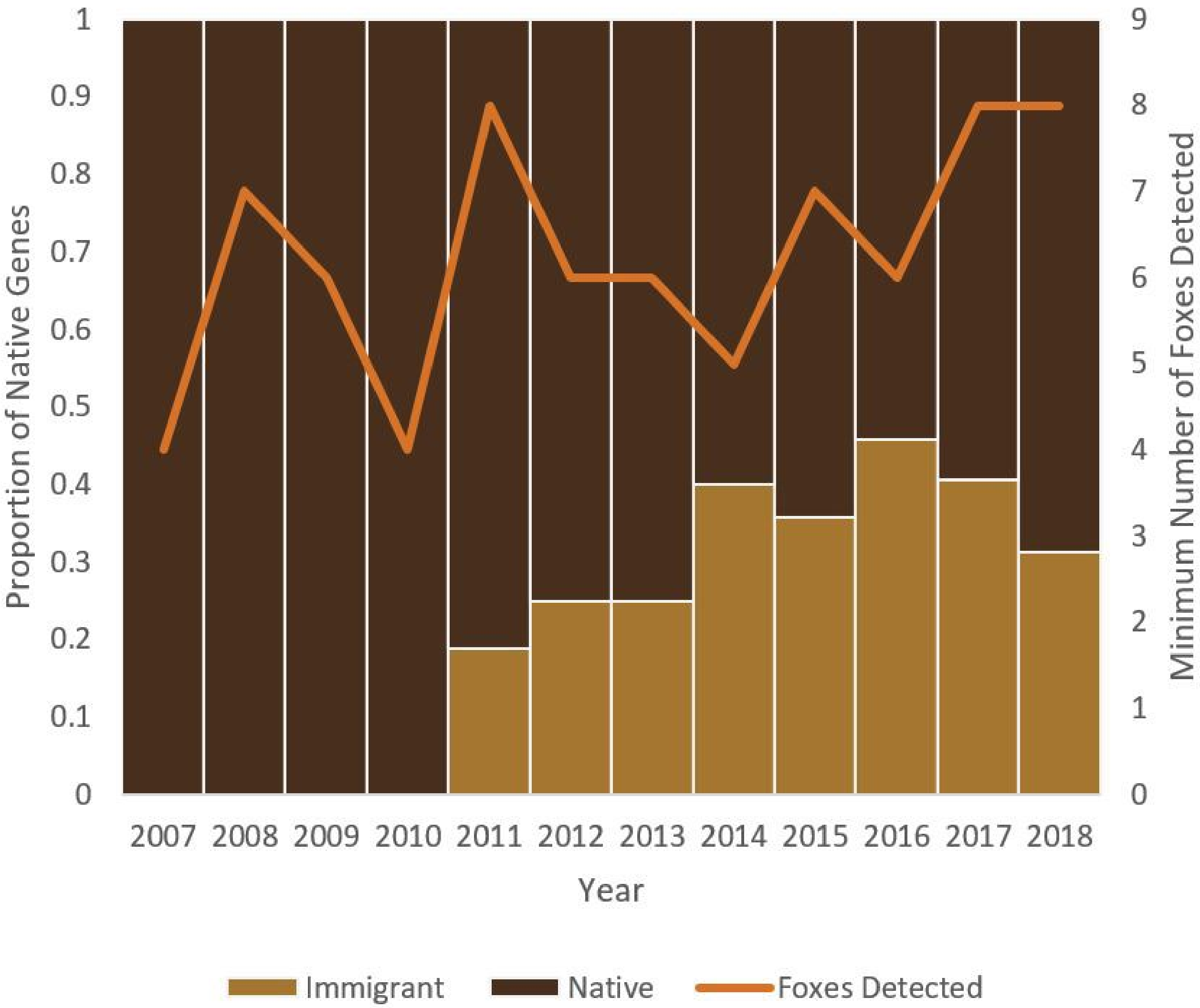


Figure 47. Proportion of native vs. immigrant ancestry in the Lassen population during 2007-2018 (CDFW and C. Quinn, UC Davis, unpublished data).

and other resources that may be limited in low-productivity mountain environments. The potential for competition with coyotes and gray foxes is of particular concern given the similar niches occupied by these species. Long-term carnivore monitoring data from the southern Sierra Nevada show a 25–30% increase since 2012 in gray fox occupancy above 2,000 m (Tucker et al. 2019). Gray foxes have been detected recently by remote cameras and genetic samples in or near habitat known to be occupied by SNRF in the Lassen, Sonora Pass, YNP, and Ritter Range study areas (Figure 49; NPS, unpublished data). While competitive relationships between gray foxes and red foxes have not been well studied, both species utilize similar prey items, and gray foxes, as more generalist omnivores, may have a competitive advantage over red foxes where they co-occur, if habitat is suitable (Hockman and Chapman 1983; Cypher 1993). If gray foxes increase in density in SNRF habitat, the potential for interspecific competition will also increase.

A substantial body of literature demonstrates competitive interactions between coyotes and red foxes in other regions. While no studies have documented interactions between SNRF and sympatric coyotes, inverse relationships exist

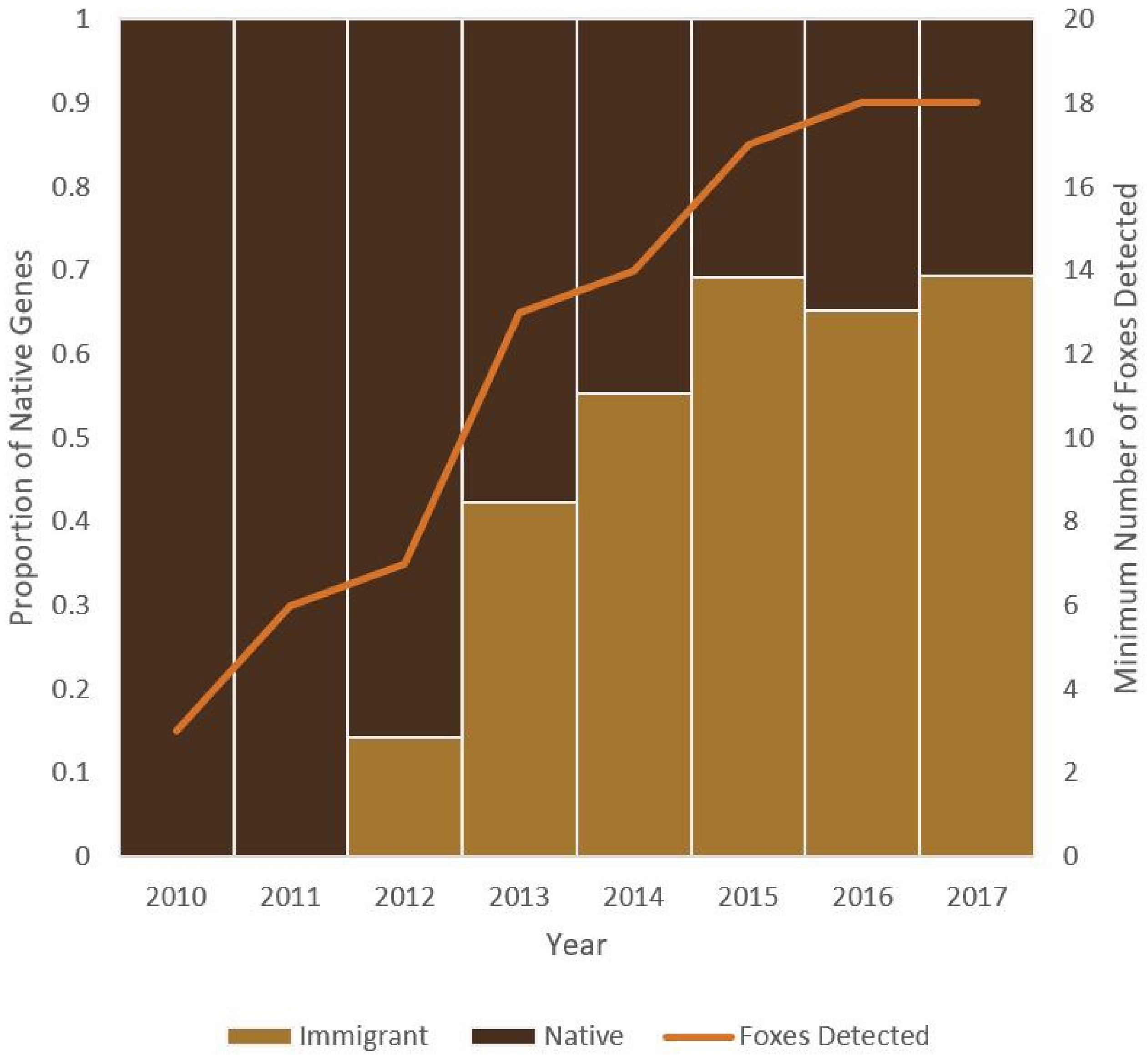


Figure 48. Proportion of native vs. immigrant ancestry in the Sonora Pass study area during 2010-2017. Adapted from Figure 6b in Quinn et al. 2019.

between the densities of coyotes and red foxes at regional scales elsewhere in North America (Linhart and Robinson 1972; Harrison et al. 1989; Levi and Wilmers 2012; Newsome and Ripple 2014). Red foxes may avoid coyotes within their home ranges (Gosselink et al. 2003), and individual coyotes have been observed killing (Sargeant and Allen 1989; Gosselink et al. 2007) and chasing (Dekker 1983) red foxes.

Coyotes co-occur with SNRF in the Lassen study area, although they may be more common in SNRF habitat in summer than winter (CDFW, unpublished data). Coyotes were historically common in the Sierra Nevada (Grinnell et al. 1937), and substantial contemporary evidence suggests the year-round presence of coyotes sympatric with SNRF in the Sierra Nevada's subalpine and alpine zones (Figure 50; Hatfield et al. 2020; Quinn 2018; CDFW, unpublished data; NPS, unpublished data). In the coniferous forests of Oregon and Washington, coyotes were reportedly rare until the 1930s (Witmer and DeCalesta 1986; Toweill and Anthony 1988; Verts and Carraway 1998), but recent remote camera surveys in the Central Cascades study area documented the use of high-elevation terrain by coyotes in winter (McFadden and Hiller 2015).

Previous conservation assessments suggest that decreasing snowpacks caused by anthropogenic climate change and forest fragmentation from logging and other land-use practices may facilitate the encroachment of coyotes into subalpine habitat (Perrine et al. 2010; USFWS 2018). Snow compaction from grooming and over-snow vehicle (OSV) recreation may be an additional mechanism that could alter coyote movement patterns. Studies in northwestern Wyoming and northeastern Utah found that coyotes appeared to select for snowmobile trails, particularly in areas of deep, uncompacted snow (Bunnell et al. 2010; Gese et al. 2013), whereas in western Montana, coyotes selected for areas of shallower snow but did not use snowmobile trails to an extent disproportionate to their availability (Kolbe et al. 2007). Any encroachment by coyotes due to snowmobile trails would likely be minimal and restricted to a few small areas outside of designated wilderness where OSV use overlaps with occupied SNRF habitat.

Competition requires more than just sympatry, and so an increase in coyote density in SNRF habitat may not necessarily result in intensified competition if resources are sufficient to support both species or if the species partition their use of resources. However, the diets of coyotes and red foxes are likely similar (in Oregon, Poisson et al. 2019 found a 65% overlap in diet), and it is reasonable to assume that prey availability is limited to some extent in low-productivity alpine environments, particularly in the winter and spring months when energetic demands are highest for both species. If competition is occurring between coyotes and SNRF, its consequences could take many forms at many levels of severity. Spatial segregation has been documented in other sympatric coyote and red fox populations (Gosselink et al. 2003), and can result in the subordinate species occupying suboptimal habitat (Perrine et al. 2010), but this is not well studied in SNRF populations. Competition could also result in reduced survival for adults or juveniles. Recruitment rates of juvenile SNRF are not well known, but although sample sizes are small, individual-based monitoring in the Lassen and Sonora Pass study areas indicates adults are fairly long-lived (Figure 12; Figure 13). Reduced reproductive output due to competition for prey resources is another possible outcome of exploitation competition with coyotes, gray foxes, or other carnivores (e.g., Creel and Creel 1996; Caro and Stoner 2003; Watts and Holekamp 2009).

Figure 49. A gray fox photographed by remote camera in LVNP at a site where SNRF were also detected. Photo courtesy of NPS, August 2018.

Climate change will likely cause shifts in the dynamics of species interactions, although precise outcomes are difficult to predict. As winter snowpack declines and rain-on-snow events increase in frequency, lower elevation canids, such as the gray fox, may increase in abundance at higher elevations, and SNRF may have a lessened competitive advantage (Perrine et al. 2010; Cross 2015; Tucker et al. 2019). Predicting future competitive dynamics would also require investigating how prey availability is likely to change under different climate change, land management,

Figure 50. A coyote photographed by remote camera in the Mono Creek study area at a site where SNRF were also detected. Photo courtesy of CDFW, January 2018.

and recreation scenarios.

## III.A.7. RECREATION, HABITUATION, AND DEVELOPMENT

In a broad review of wildlife responses to recreation across multiple taxa, Mills et al. (2020) summarized many apparent negative effects of recreation on carnivores, including habitat fragmentation, displacement from habitat, alteration of activity patterns, and changes in movement behavior. These effects were documented in numerous carnivore species, such as mountain lions (Reilly 2015), wolves (Hebblewhite and Merrill 2008), coyotes (George and Crooks 2006; Barrueto et al. 2014; Reilly et al. 2017), bobcats (George and Crooks 2006), wolverines (Krebs et al. 2007; Heinemeyer et al. 2019), and Canada lynx (Olson et al. 2018). While such effects have not been studied or documented in SNRF, they constitute potential threats to the subspecies.

Availability of food and trash has been shown to cause habituation of wildlife to humans through food conditioning. Habituation can result in abnormal diet, human-wildlife conflicts, and mortality from vehicle strikes, pet aggression, or transmission of disease from infected pets. Habituation in SNRF has been documented in California (Figure 51; Lassen and Sonora Pass study areas, Perrine 2005; CDFW, unpublished data; USFS, unpublished data) and Oregon (Hoodoo ski resort, Mt. Bachelor ski resort, Mt. Hood Meadows ski resort, CLNP, NPS, unpublished data; ODFW, unpublished data), in Cascade red foxes in Washington (Mt. Rainier National Park, Crystal Mountain Resort, Mt. Adams; Jenkins et al. 2014, J. Akins, Cascades Carnivore Project, unpublished data), and in Rocky Mountain red foxes in Grand Teton National Park (T. Hiller, Wildlife Ecology Institute, personal communication 2019). Availability of food and trash may also disproportionately benefit sympatric carnivores such as coyotes that may compete with SNRF.

It is unclear to what extent SNRF modify their behavior or avoid areas with recreation or development. In general, red foxes may be more tolerant of humans than some other carnivore species, as demonstrated by their successful adaptation to human-dominated environments worldwide (Harris and Smith 1987; Kurki et al. 1998; Wandeler et al. 2003; Luniak 2004), and their documented use of trails and human-disturbed areas (Joslin and Youmans 1999; Lenth et al. 2008; Corlatti et al. 2009; Ordenana et al. 2010; Pouwels and van der Grift 2012; Mills et al. 2020). However, responses of SNRF to human presence have not been studied systematically. In remote wilderness areas, montane red foxes have shown a range of behaviors from avoidance of survey stations to repeated entering of baited traps (J. Akins, Cascades Carnivore Project, personal communication 2019; T. Hiller, Wildlife Ecology Institute, personal communication 2019; C. Quinn, UC Davis, personal communication 2019), suggesting that SNRF individuals likely vary in their behavioral responses to human presence.

Development in the form of road and trail building or other construction may fragment SNRF habitat due to new, intensified, or dispersed human disturbance that reduces areas of previously contiguous interior habitat into patches with varying degrees of anthropogenic influence, which may equate to varying habitat quality. Development may also alter vegetation composition by extending the spread of invasive plants, or may facilitate movement of coyotes and other potential competitors into SNRF habitat (Gese et al. 2013; Smith et al. 2018). Compaction of snow by OSVs and ski resorts may restrict subnivean habitat for small mammal prey (Schmid 1972; Sanecki et al. 2006). We do not currently have the information to quantify these potential indirect impacts to SNRF.

Outdoor recreation may be increasing throughout SNRF habitat, and may have greater impacts on SNRF in the future. Increasing habituation may contribute to a rise in vehicle strikes, as well as the possibility of human-wildlife conflicts.

### III.A.7.1. LASSEN

Annual visitor numbers at LVNP increased from 374,911 in 2000 to 517,039 in 2019 (NPS, unpublished data). The park and its vicinity experience high visitation rates in summer, predominantly from hikers and campers. In winter, visitors are concentrated in the southwest portion of LVNP, the Manzanita Lake area in the northwest part of the park, and the Eskimo Hill winter recreation area of the Lassen National Forest north of the park. South and east of the park, USFS maintains groomed snowmobile trails. Begging foxes were observed in the Lassen study area through the early 2000s (Perrine 2005), but not in recent years. Recent collar data show SNRF sometimes visit the Eskimo Hill winter recreation area, typically at night when humans are not present (CDFW, unpublished data).

Figure 51. A cross-pelage SNRF begging for food at a campsite near Sonora Pass in April 2016. Photo courtesy of Steve Cosner.

### III.A.7.2. SIERRA NEVADA

The Sonora Pass study area supports a wide variety of human uses. Each spring, summer, and fall, thousands of hikers travel the Pacific Crest Trail, which traverses nearly the entirety of known occupied habitat in the Sonora Pass study area. The Bridgeport Winter Recreation Area (BWRA) directly overlaps the majority of SNRF detections from the Sonora Pass study area. Both OSV and non-motorized winter recreation occur in this area. Levels of use vary across years. Data for not-motorized use are not available. OSV use ranged from 127 reported user days in 2012 to 1,152 user days in 2019 (USFS, unpublished data).

The Marine Corps Mountain Warfare Training Center (MCMWTC) conducts a variety of motorized and non-motorized activities in the Sonora Pass study area year-round, with training events in the winter involving up to 120 participants. These training activities are conducted under a 40-year special use permit from USFS, which stipulates that measures must be taken to prevent habituation of SNRF to anthropogenic food, that all trash and food must be stored so that it is inaccessible to wildlife and removed after training activities, and that no disturbance is permitted within 100 m of den sites between March 1 and June 30 (U.S. Marine Corps 2019). Ongoing monitoring, and corrections when non-compliance is discovered, are designed to eventually eliminate the concern of improper trash management leading to habituation of SNRF.

Visitor numbers in YNP increased from 3,400,903 in 2000 to 4,422,861 in 2019. Although a minority of visitors to YNP enter areas occupied by SNRF, this increase in visitor numbers is also reflected in the portion of the park where SNRF have been detected (NPS, unpublished data). The heavily used Pacific Crest Trail passes near areas of known SNRF occurrence in the YNP and Ritter Range study areas, albeit at lower elevations than those of SNRF detections. Visitor use information is not available for the Mono Creek study area, but anecdotal observations suggest that this area experiences far less human use than the Sonora Pass, YNP, or Ritter Range study areas.

### III.A.7.3. OREGON

Throughout Oregon, USFS has seen an increase in requests for special use permits for events, which can bring large numbers of people, dogs, food, and trash onto National Forest lands and into SNRF habitat. On the Deschutes National Forest (which overlaps the Central Cascades study area), approximately 600 special use permits are issued annually and events occur frequently year-round. Use monitoring shows a 60% increase in recreation activities on the Deschutes National Forest since 2014 with approximately 3,800,000 visitors per year (USFS, unpublished data). Data gathered from an ongoing collaring study of SNRF in the Central Cascades study area suggest that SNRF utilize areas of developed, high-intensity recreation at all times of year, appearing to follow the concentration of human activity by shifting from ski resorts in winter to nearby campgrounds during the spring, summer, and fall (ODFW, unpublished data).

In CLNP, visitor numbers increased from 426,883 in 2000 to 704,512 in 2019 (NPS data). NPS staff estimate that more than 95% of visitor use in CLNP occurs within SNRF habitat (S. Mohren, NPS, personal communication 2019). During 2013–2015, 2 SRNF individuals were frequently observed in some of the most populated areas of CLNP. One of the individuals was killed by a vehicle strike in 2013, but the other continued to visit heavily used areas, interact with humans, and beg for food until 2015, when reports of this behavior ceased (S. Mohren, NPS, personal communication 2019).

## III.A.8. FOOD AVAILABILITY

Previous assessments of food habits of SNRF emphasized summer diet, which is likely less limiting than winter and spring diet, when food is generally more scarce and energetic needs associated with reproduction are higher. During winter and spring, carrion and larger-bodied prey species such as snowshoe hares and white-tailed jackrabbits may be particularly important food sources, although their availability is unknown. Any limitation in food resources during this critical period of the year may have negative consequences for SNRF survival and reproduction.

Rabbit Hemorrhagic Disease Virus serotype-2 (RHDV-2) was detected in 2020 in both wild and domestic lagomorphs in southern California. This highly lethal disease has the potential to spread rapidly and cause significant mortality in California lagomorph populations, including those that co-occur with SNRF. Declines in high-elevation snowshoe hare and white-tailed jackrabbit populations could reduce available prey for SNRF (D. Clifford, CDFW, personal communication 2020).

Investigating seasonal variation in prey composition is key to elucidating whether SNRF are food-limited. If a limitation exists, it may take effect through reduced reproductive output due to insufficient resources in the winter and spring, rather than through direct mortality by starvation. Competition with other carnivores may also affect food availability for SNRF to an unknown extent. Finally, we do not know the effects of consumption of anthropogenic food sources on SNRF, although it is clear that many processed foods are toxic to wildlife (e.g., Beringer et al. 2016).

## III.A.9. PREDATION

Predation has the potential to affect all SNRF populations through adult and juvenile mortality. Several North American studies or observers have documented coyote predation on red foxes (Sherburne and Matula 1980; Maine Cooperative Wildlife Research Unit, unpublished report; Sargeant and Allen 1989; Gosselink et al. 2007). Coyote predation has been identified as the primary cause of mortality in swift fox populations (Sovada et al. 1998; Olson and Lindzey 2002; Kamler et al. 2003) and some kit fox populations (Cypher and Scrivner 1992; Ralls and White 1995; Cypher and Spencer 1998). SNRF may also alter their use of space or prey resources in response to predator presence, perhaps resulting in lower fecundity or recruitment. Possible occasional predators of red foxes also include gray wolves, mountain lions, badgers, martens, wolverines, domestic dogs (Larivière and Pasitschniak-Arts 1996), golden eagles (Grinnell et al. 1937; Tjernberg 1981), and bobcats (Grinnell et al. 1937; J. Bowles, ODFW, personal communication 2021).

We have only 3 contemporary records of predation on SNRF: an individual was killed by a domestic dog at Lassen (Perrine 2005), and 2 mortalities in the Central Cascades study area were classified as potential predation (1 carcass appeared to have been killed by a coyote, and 1 was likely killed by a bobcat; J. Bowles, ODFW, personal communication 2021). Individual-based monitoring data from the Lassen and Sonora Pass study areas indicate adults are fairly long-lived (Figure 12; Figure 13), suggesting that predation may not be reducing adult survival in these populations. We have no cause-specific mortality data for juvenile age classes, which may be the most susceptible to predation and whose loss might have the most serious repercussions for population growth.

## III.A.10. DISEASE

Foxes are known to be susceptible to a variety of diseases. Sarcoptic mange has caused significant declines and local extirpations of red foxes in England (Baker et al. 2000), Sweden (Danell and Hornfeldt 1987), and recently on Fire Island National Seashore in New York (NPS, unpublished data). Canine distemper was the probable cause of the decline of the Santa Catalina Island fox population from more than 1,300 individuals to 103 during 1999–2000 (Timm et al. 2009). Canine distemper is generally common and highly fatal in *Urocyon* species (Timm et al. 2009; USFWS 2015b), although *Vulpes* species appear relatively less susceptible. Canine distemper virus is the most commonly diagnosed disease causing mortality in gray foxes submitted to the CDFW Wildlife Investigations Lab (unpublished data) and cases have been diagnosed near current SNRF habitat in the Lassen and Mono Creek study areas. Rabies has caused large numbers of red fox mortalities in Europe, partly due to the species' widespread abundance on that continent (Wandeler 2004). In California, bats and skunks are the primary reservoirs for the rabies virus, but all mammals, including SNRF, are susceptible to infection (Black and Lawson 1970), which is invariably fatal (Rupprecht 2001). Although rabies detections in carnivores near SNRF habitat are extremely rare (California Department of Public Health, unpublished data), the chance occurrence of a rabies case in SNRF could pose a serious conservation threat given the current small population size.

While systematic testing of SNRF has not taken place, to date there has been no evidence of diseases causing morbidity or mortality in SNRF in California (Perrine et al. 2010; CDFW, unpublished data) or Oregon (ODFW, unpublished data). However, disease is among the plausible explanations for historical declines in SNRF populations, along with over-harvest and exposure to toxins used for predator control.

In the Lassen population, fleas were the only ectoparasites observed on captured foxes during 1998–2002 (Perrine 2005) and 2018–2020 (CDFW, unpublished data). An examination of fresh fecal samples from 3 individuals during 2001–2002 identified ova from lung fluke, tapeworm, and roundworm species. A necropsy of the individual killed by a dog in 2002 revealed 38 ascarids (presumed *Toxascaris leonina*) in the small intestine. Flotation by centrifugation of fecal samples from 6 female SNRF captured between 2018–2020 revealed mild to moderate endoparasite burdens in 5 of the 6 foxes. Lungworm ova (*Alaria* sp.) were detected in 5 SNRF, presumed *Toxascaris leonina* ova in 2 SNRF, and ova of an unidentified hookworm in 1 SNRF. Planning is underway to conduct serology and PCR testing for canid infectious diseases on samples from SNRF captured during 2018–2020 in the Lassen study area (D. Clifford, CDFW Wildlife Investigations Lab, personal communication 2020).

Full post-mortem examination and testing of the SNRF killed by a vehicle strike in the Sonora Pass study area in 2011 detected cestode parasites in the intestines with no associated tissue damage, and a mild to moderate number of protozoal cysts in the masseter, psoas, hindleg, and foreleg muscles. However, neither finding would have caused impairment of this individual (CDFW California Animal Health and Safety Lab and UC Davis, unpublished data).

Foxes captured at high elevations in the Central Cascades study area in Oregon have not had ectoparasite infestations (e.g., ticks, lice, fleas), but fleas and other external parasites have been noted at lower elevations both west and east of the Cascades (J. Bowles, ODFW, personal communication 2019).

Currently there is no evidence that these parasites are causing illness in SNRF. However, intestinal parasites must absorb nutrients from their host to survive and reproduce, damaging the inner intestinal lining and causing irritation and inflammation, which can be worsened when parasite burdens become severe. For animal hosts in poor health or with high metabolic and nutrient demands (e.g., young animals or reproductively active animals), an excessive parasite burden could cause illness, such as vomiting, diarrhea, and lack of appetite (Bowman 1995).

It is difficult to predict whether the risk of disease to SNRF will increase in the future. USFWS SSAs (2015, 2018) determined that the level of disease threat is not likely to change; however, increased occurrence of domestic pets, other wild carnivores, infected fish (i.e., salmon poisoning disease), or other disease vectors in SNRF habitat could elevate the risk of disease transmission. Human recreation in SNRF habitat can increase exposure of SNRF to pets (especially domestic dogs), which may act as vectors for disease, particularly if SNRF become habituated to humans and pets, as with the Santa Catalina Island fox (Clifford et al. 2006; Timm et al. 2009). Climate change may facilitate movement of other carnivores into SNRF habitat, providing more avenues for disease transmission, and may also enable the overwintering of external parasites like fleas. Inbreeding depression, if present in SNRF populations, could result in depressed immunity, rendering SNRF individuals more vulnerable to disease (Soulé 1980; Gilpin 1987; O'Brien 2003).

Limited connectivity between SNRF populations might prevent disease transmission from one population to another (Perrine et al. 2010; USFWS 2018). However, GPS collar data from the Lassen population shows considerable spatial overlap between individuals (CDFW, unpublished data), suggesting that disease transmission could occur readily within populations. The introduction of any fatal disease to SNRF populations could present a major threat to the long-term persistence of those populations.

## III.A.11. HUNTING AND TRAPPING

Hunting and trapping of red foxes in California was prohibited in 1974. In Oregon, hunting and trapping red foxes is permitted with a furtaker's license during the open season (October 15–February 28), except within the CLNP study area. During 1989–2017, trapping accounted for 92% of the total harvest of red foxes statewide. Harvest reporting includes species and county, but does not differentiate between SNRF and other red fox subspecies. Total red fox harvest during 2009–2018 (presumably including multiple red fox subspecies) averaged 20 per year from all 12 counties which encompass the historical range of SNRF in Oregon along the Cascades crest (Figure 52). These counties also contain red fox populations of other subspecies, and communication with furtakers suggests that minimal trapping activity occurs in areas occupied by SNRF. Red fox pelts have brought low prices in recent years, and trappers report that they typically release captured red foxes, though in rare instances red foxes injured in traps have been killed (J. Bowles, ODFW, personal communication 2019). Although a detailed analysis has not been conducted, the current level of harvest in the Oregon SNRF range is not known to be, or considered by ODFW to be, a threat to the SNRF population. Previous conservation assessments concluded that hunting and trapping could act as a low-level stressor to the population, but the potential effects have not been quantified (USFWS 2015b, 2018).

## III.A.12. LAND USE AND MANAGEMENT

Various land uses may threaten SNRF by reducing or degrading available habitat, altering movement patterns or denning behavior, or causing direct mortality. However, without a clear understanding of SNRF selection for specific habitat attributes, it is difficult to determine whether any land management activities directly impact SNRF. Instead, we highlight potential effects of such activities on the small mammal populations that comprise the bulk of SNRF prey, reasoning that SNRF habitat selection is likely influenced by prey abundance. Small mammal responses to the activities described below vary by species and land cover type. Where the information is available, we discuss species- and location-specific impacts, and we primarily present results from studies performed in montane, subalpine, or alpine environments that may be similar to areas occupied by SNRF.

The land use and management practices described below only constitute potential threats where they occur in SNRF habitat. We define SNRF habitat as areas known to be occupied by SNRF (i.e., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the subspecies' historical range (e.g., Green et al. in preparation; Stermer in preparation).

## III.A.12.1. FIRE SUPPRESSION AND WILDFIRES

Fire suppression can change forest structure by increasing stand density, reducing understory plant diversity and abundance, and reducing the extent of meadows or other openings in the forest by facilitating tree and shrub encroachment (Franklin et al. 1971). Over time, these structural changes diminish suitable habitat for some small mammals and increase the likelihood of catastrophic wildfires that can degrade forest habitat for long periods of time. In the long term, restoring natural fire cycles can increase small mammal abundance and meadow extent (Fisher and Wilkinson 2005), thereby presumably improving habitat for SNRF.

The effect of fire cycles on SNRF habitat will likely be greater in regions where SNRF use more montane forests (e.g., Lassen, Oregon) as opposed to alpine and subalpine zones, where the fire season is short and large-scale disturbances are less frequent (e.g., Sierra Nevada, Schoennagel et al. 2005; Sibold and Veblen 2006). However, as the climate warms, changes to the vegetation composition in higher elevation regions may result in more frequent wildfires there (e.g., Rocca et al. 2014; Kerns et al. 2018).

## III.A.12.2. SILVICULTURAL TREATMENTS

Silvicultural treatments are uncommon in alpine and subalpine zones, and are therefore unlikely to

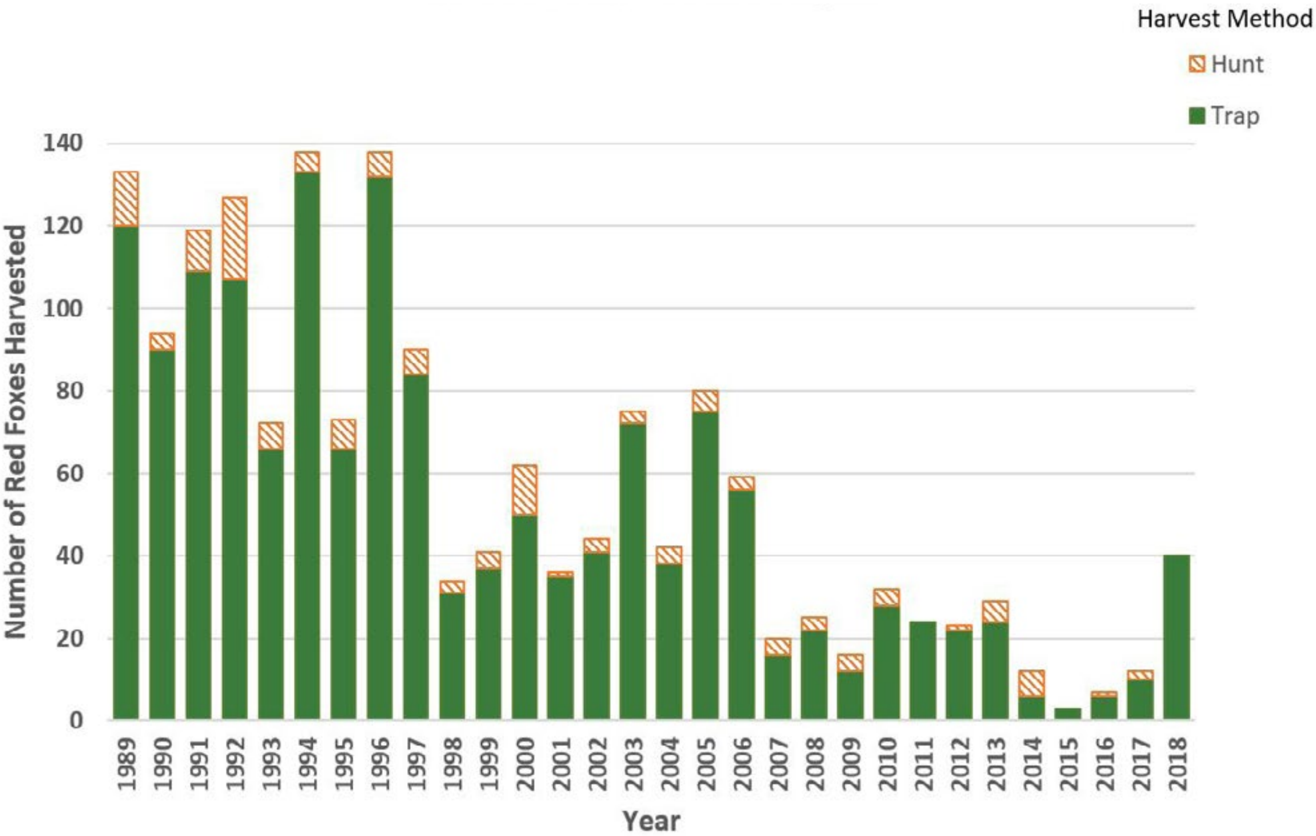


Figure 52. Annual harvest of red foxes across 12 counties which encompass the historical range of the SNRF in Oregon during 1989–2018, based on mandatory harvest reports (ODFW, unpublished data).

impact the majority of known SNRF habitat in the Sierra Nevada or the upper elevations of known habitat in Lassen and Oregon. However, in areas where SNRF make use of montane forests (e.g., mid-elevation areas where SNRF have been detected in western LVNP, in the Caribou Wilderness east of LVNP, east of Sonora Pass in the Sierra Nevada, and in the Central Cascades of Oregon), silviculture projects may occur and have the potential to affect prey populations.

Silvicultural treatments can vary substantially in their effect on different small mammal species. Many forest-floor-dwelling and generalist small mammals rely on structural components of forest understories such as shrubs and woody debris that can be affected by silvicultural treatments. In mature forests in the Western Cascades of Washington, small mammals were more abundant in unburned clearcuts, where more woody debris was added to the forest floor, than in burned clearcuts or untreated stands (Gunther et al. 1983). Red-backed voles were associated with undisturbed or old-growth stands in southwest Canada, north-central Ontario, and western Montana, and were less abundant in stands with harvest or prescribed fire treatments (Martell 1983; Sullivan et al. 2000; Zwolak and Foresman 2007; Zwolak 2009). Red squirrel density in mixed-conifer forests in Idaho and Washington increased with shrub cover and density of downed logs (Russell et al. 2010). Snowshoe hares in Oregon, Idaho, and northwest Montana were more abundant in untreated stands or patch cuts than in areas subject to traditional precommercial thinning (Ausband and Baty 2005; Bull et al. 2005).

Compared to pre-harvest conditions, some harvest regimes increase the amount of woody debris on the forest floor and may benefit certain small mammal species. A meta-analysis of small mammal responses to forest treatments in North America found that yellow-pine chipmunks, meadow voles, and long-tailed voles increased after recent clearcutting when slash was not removed (Zwolak 2009). In clearcuts and strip cuts in Ontario, deer mice were most abundant after cutting (Martell 1983), and yellow-pine chipmunks increased after logging in Idaho (Medin and Booth 1989). Snowshoe hare density and recruitment increased 1 year after thinning of lodgepole pine stands produced ample food and cover on the forest floor, but later declined significantly (Sullivan and Sullivan 1988). Slash piles and windrows in clearcuts provided habitat structure that increased red-backed vole abundance and species richness of forest-floor-dwelling small mammals in British Columbia (Sullivan et al. 2012). Other small mammals, such as golden-mantled ground squirrels, may be associated with more open forest habitats without significant understory structure, and may not be affected by loss of cover (Shick et al. 2006).

In general, timber harvest, fuels reduction, vegetation treatments, and fires that remove understory structures are likely to have a greater adverse impact on SNRF prey species than treatments that preserve some aspects of understory complexity. The level of impact may vary depending on the spatial distribution and heterogeneity of treatments; treatments that maintain or enhance landscape heterogeneity may improve habitat quality for a diversity of species (e.g., Carey and Wilson 2001). It is important for land managers to remember that the effects of management activities on small mammal abundance may unfold over multiple years, and in some cases short-term increases may be followed by declines (as with snowshoe hares after thinning treatments in British Columbia, Sullivan and Sullivan 1988). Shifts in the abundance of prey species after management may be more problematic for SNRF if the timing of prey availability does not correspond to the SNRF reproductive cycle, when energetic demands for prey resources are highest.

## III.A.12.3. LIVESTOCK GRAZING

In some habitats, sheep and cattle grazing has a negative effect on the composition of small mammal communities, measured in terms of abundance, density, occupancy, peak biomass, or species richness and diversity (Medin and Clary 1989; Moser and Witmer 2000; Schmidt et al. 2005; Ważna et al. 2016; Horncastle et al. 2019). However, differential responses detected in certain species suggest that grazing may result in increased density of small mammals that require less vegetative cover (e.g., some leporids, which may rely more on burrows than vegetation as cover; Karmiris and Nastis 2006; Bakker et al. 2009), while simultaneously reducing the density of small mammals that prefer more cover (e.g., some voles, shrews, and mice; Johnson 1982; Ważna et al. 2016; Shultz and Leininger 1991). Horncastle et al. (2019) suggest that grazing is more likely to impact small mammal species with small home ranges or those for which forage biomass or availability of specific vegetation types are limiting factors.

In high-elevation meadows, the effects of grazing on small mammal populations are not well studied. In the Tatras Mountains of Poland, total small mammal abundance and species richness were lower in montane glades grazed by sheep, but 1 vole species (*Microtus arvalis*) was more abundant in grazed meadows with low sheep density than in ungrazed areas (Ważna et al. 2016). In Arizona, small mammal species richness was similar between grazed and ungrazed sites, but occupancy was lower for deer mice, Navajo Mogollon voles, and thirteen-lined ground squirrels in montane meadows grazed by cattle (Horncastle et al. 2019). Because SNRF are generalist predators rather than specialists in a particular prey species, abundance, density, peak biomass, and occupancy of small mammals are likely more relevant metrics of food availability than species richness or diversity.

Grazing may be implicated to some extent in tree and shrub encroachment on meadows, though climate change, perhaps in combination with fire suppression, is likely a more influential mediator of this process (Franklin et al. 1971; Halpern et al. 2010). Some studies also suggest that while disturbance from grazing may facilitate tree encroachment, grazing may simultaneously contribute to the short-term maintenance of meadows by hindering tree development (e.g., Helms 1987; Miller and Halpern 2009).

Overall, livestock grazing may not pose a specific threat to SNRF because in most populations there is little overlap between occupied SNRF habitat and grazing allotments in current use. In the Lassen population, GPS collar data suggest that SNRF use during the summer grazing season is concentrated in LVNP and the Caribou Wilderness, areas without cattle allotments (Figure 53; P. Figura, CDFW, personal communication 2019). In the Sierra Nevada, the Sonora Pass study area contains several active sheep and cattle grazing allotments that overlap with areas where SNRF have been detected (Figure 54). Grazing in this area is required to maintain at least 60% cover in late seral meadows and is excluded from standing water and saturated soils in occupied Yosemite toad habitat (USFS 2004); it is unclear how these prescriptions may affect small mammal populations. Grazing is not permitted in YNP, and there are no active grazing allotments in the Ritter Range or Mono Creek study areas. Grazing allotments in Oregon do not occur within known SNRF habitat, but the distribution of SNRF in Oregon is not fully documented and may intersect some higher elevation allotments (L. Turner, USFS, personal communication 2019).

### III.A.12.4. OTHER LAND USES

Cannabis cultivation is more common at lower elevations than those occupied by SNRF, but may occur in SNRF habitat; see III.A.3. Rodenticides. Carnivores have been killed by toxicants placed by some cannabis growers to reduce herbivore populations (Gabriel et al. 2012).

Recreation, development, and special use permits may entail impacts to SNRF habitat or prey populations; these potential threats are discussed

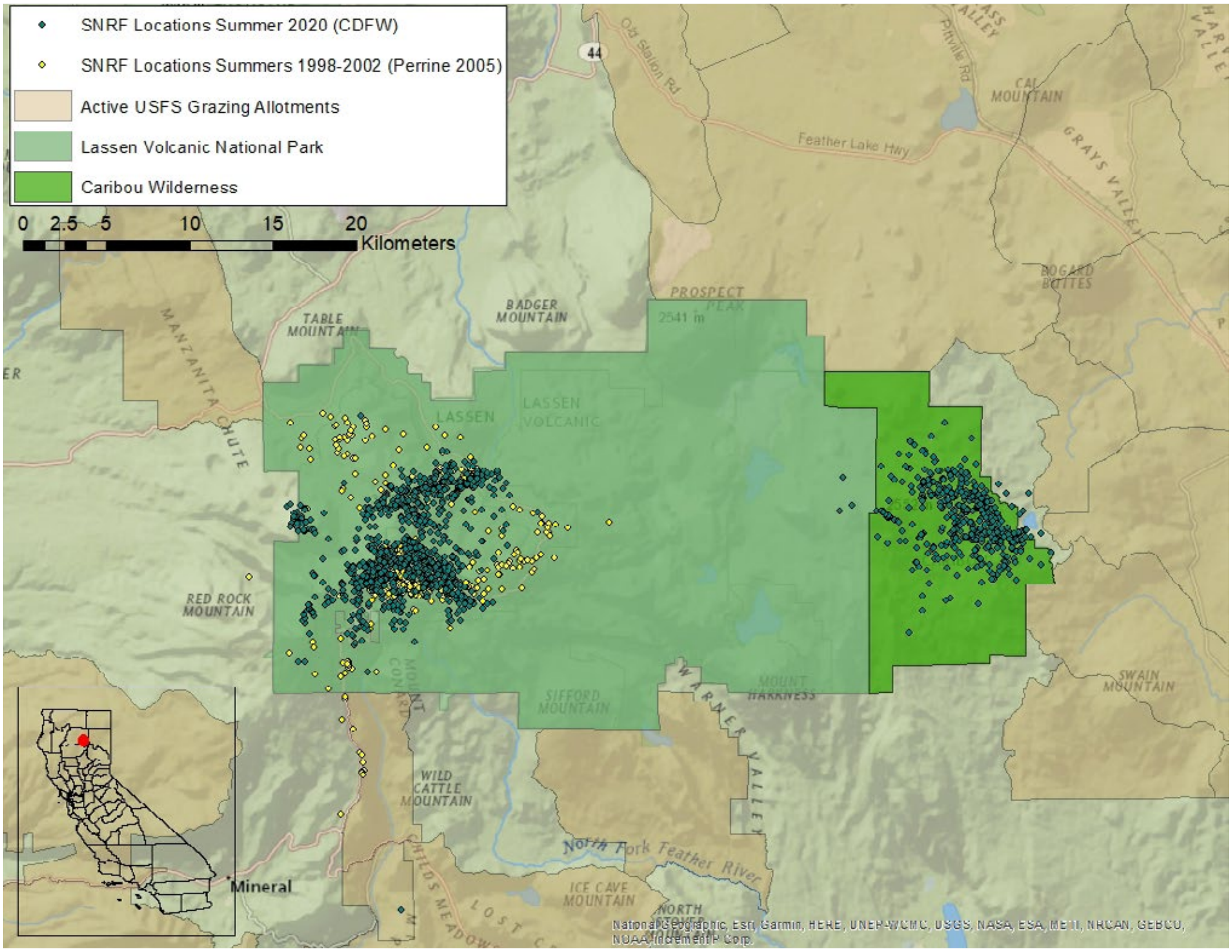


Figure 53. Grazing allotments in the Lassen Peak region and locations of SNRF during the summer grazing season (June 15-September 15). Yellow dots are telemetry locations from 5 collared SNRF, camera detections, and SNRF observations during 1998-2002 (Perrine 2005). Blue dots are GPS locations from 4 collared SNRF in 2020 (CDFW, unpublished data).

under III.A.7. Recreation, Habituation, and Development.

We have no evidence that SNRF populations are impacted by any of the land use and management activities enumerated above. Better characterization of SNRF habitat associations and prey preferences may permit researchers to evaluate any effects and recommend best practices for land management in SNRF habitat.

## III.A.13. CUMULATIVE IMPACTS OF POTENTIAL THREATS

Potential threats must be considered in context as well as individually. Small population size and climate change could exacerbate the effects of numerous other potential threats, posing a risk of greater cumulative impacts to the SNRF.

In very small populations, sources of additive mortality are of greater concern than in larger

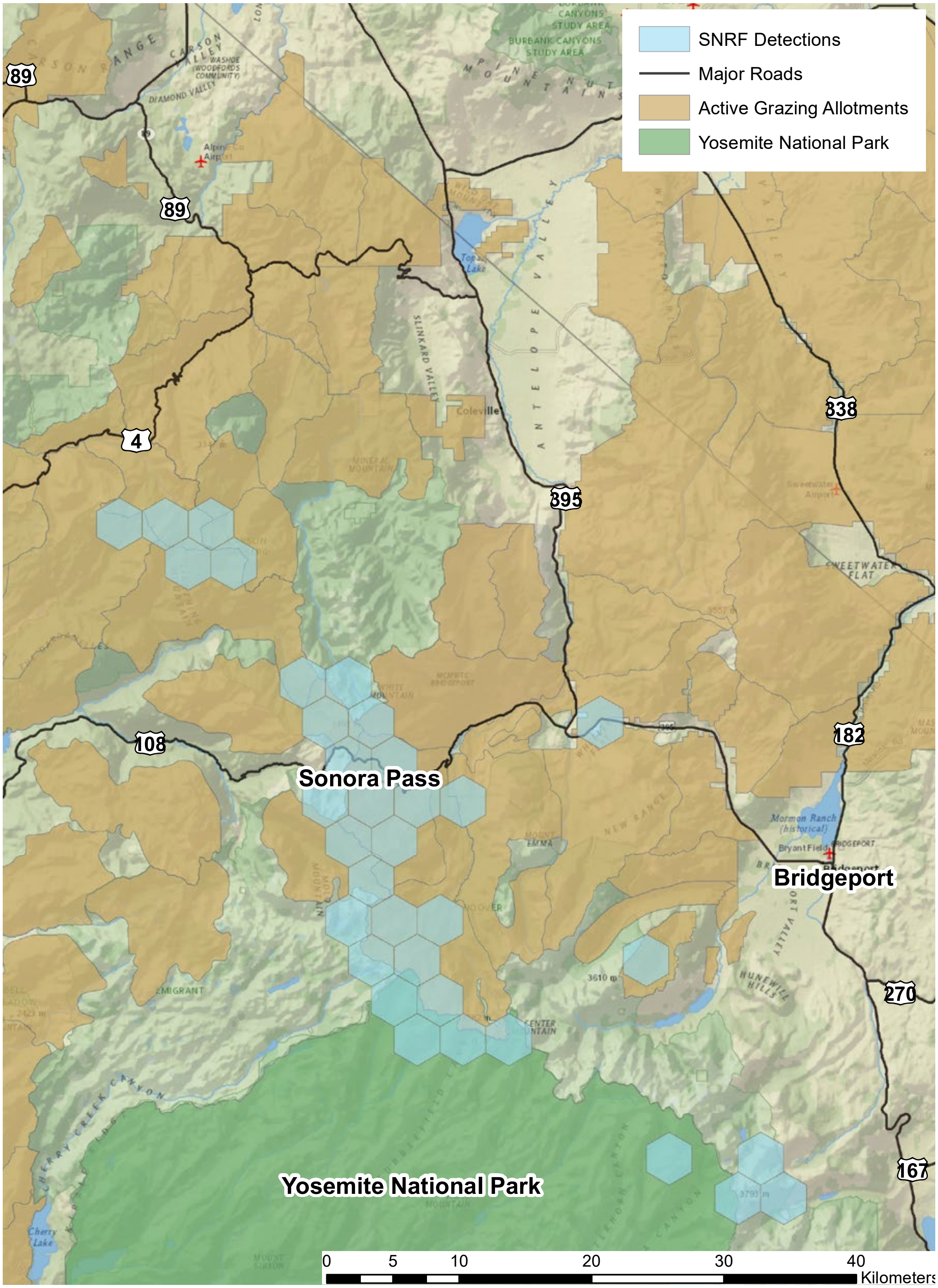


Figure 54. Overlap of sheep and cattle grazing allotments with areas of known SNRF occurrence in the Sonora Pass study area.

populations. Known or potential sources of additive mortality for SNRF include vehicle strikes, rodenticide poisoning, predation, disease, or hunting and trapping. These potential sources of additive mortality may not pose population-level risks to larger populations, but when populations are very small, the loss of even a few individuals could jeopardize their continued viability.

Small populations that experience immigration are also more susceptible than large populations to genetic swamping. Immigration and introgression, while in some cases providing needed genetic rescue of small and inbred populations, can also threaten small populations with possible loss of local genetic adaptations due to swamping.

Over time, climate change is expected to continue to alter vegetation communities and the depth and persistence of snowpacks in SNRF habitat. If prey populations are sensitive to these changes, food availability for SNRF could decline and the potential for competition with sympatric carnivores could increase. Climate change may also alter SNRF habitat in ways that make it more suitable for other carnivores (e.g., by reducing snow depth), facilitating range expansions that could lead to overlap and competition.

While the impacts of land use and management activities in SNRF habitat are uncertain, any negative effects may be intensified if habitat suitability is simultaneously diminished by climate change.

Finally, if recreation and development intensify in SNRF habitat, the risks of mortality from vehicle strikes, rodenticide poisoning, or disease may also increase.

## III.B. INFORMATION NEEDS

Although reasonable evidence supports the conclusion that multiple SNRF populations are threatened by small population size and low genetic diversity, our ability to create a clear strategy for conservation interventions is hindered by substantial gaps in our knowledge of the species. Filling those gaps is the most urgent priority of this Conservation Strategy, as noted in section I.D.2. Goals and Objectives[5]. We have identified 2 broad categories of information needs; both categories contain questions crucial to successful SNRF conservation.

Tier 1 targets our baseline uncertainty about population status and distribution. Where do SNRF occur? Where are they absent? How many SNRF are in each population and are these populations viable, both demographically and genetically? How can we answer these questions reliably over time? Addressing Tier 1 information needs will be fundamental to further conservation planning and a prerequisite to management interventions such as translocations.

Tier 2 comprises more specific inquiries into SNRF ecology and the threats that may endanger species recovery. In many cases, Tier 1 and 2 research questions lend themselves to similar approaches and may be possible to address simultaneously.

### III.B.1. TIER 1: BASELINE POPULATION INFORMATION

Tier 1 information needs can be further categorized into 2 tracks: *intensive* studies of extant populations, and *extensive* surveys to determine distribution and detect SNRF occurrence in novel areas. These 2 tracks are of equal importance and together constitute the most pressing gaps in our knowledge of the SNRF.

#### III.B.1.1. INTENSIVE TIER 1 INFORMATION NEEDS

### III.B.1.1.1. ABUNDANCE AND TREND

- Estimate abundance for each population
- Reassess periodically (at least every 3 to 5 years) to attempt to detect trends

Current estimates of abundance and growth or decline of all known populations are critical to SNRF conservation and recovery. Without such estimates, it is challenging to prioritize populations for management intervention and to evaluate whether specific management actions, such as translocations, are warranted or effective. For each population, abundance should be determined as soon as possible and reassessed periodically (at least every 3 to 5 years) to attempt to detect trends. The appropriate methods for deriving these estimates depend on the size and detectability of the population, as described in Appendix B. Concurrent monitoring of density and distribution may add important spatial information to abundance estimates.

The monitoring framework presented in Appendix B provides a general approach to repeated monitoring of known populations. As with other wide-ranging, rare carnivores, individual-based noninvasive genetic methods (e.g., spatial capture-recapture) offer under-utilized and uniquely suited tools to simultaneously monitor demographic, spatial, and genetic dynamics (e.g., Janečka et al. 2008; Broseth et al. 2010; Caniglia et al. 2014; Bohling and Waits 2015; Akesson et al. 2016; Carroll et al. 2018; Lamb et al. 2019; Quinn et al. 2019). Quinn et al. (2019) leveraged such methods to monitor SNRF abundance and density, while simultaneously estimating adult survival, annual reproduction, genetic diversity, inbreeding, introgression, and range expansion in the Sonora Pass study area. Individual-based noninvasive genetic methods are particularly suited to monitoring smaller populations where probability of detection can approximate 100%.

### III.B.1.1.2. VITAL RATES AND POPULATION VIABILITY

- Determine reproductive rates and litter sizes
- Estimate survival rates of adults, juveniles, and neonates
- Determine causes of death
- Perform population viability analyses for each population

Quantifying vital rates (i.e., reproduction and survival) of SNRF populations is fundamental to assessing population viability, modeling potential outcomes of translocation scenarios, and identifying possible factors limiting population growth. Robust conclusions will require multi-year studies, ideally in each known population.

Due to low numbers of individuals and the difficulty of capturing a representative sample of the population, noninvasive genetic approaches have proven integral to estimating survival and annual recruitment rates by constructing pedigrees using DNA derived from scat (e.g., Quinn et al. 2019).

While live-capture studies present significant challenges, collars with GPS location data and mortality sensors provide a complementary method that is better suited to assessing litter size prior to neonatal attrition and to investigating cause-specific mortality. Movement data from collars in the winter and spring can indicate the location of potential den sites, which can then be monitored with remote cameras to determine the number of pups and any den predation. Mortality sensors on collars can allow timely investigation of carcasses to determine cause of death.

### III.B.1.1.3. GENETIC MONITORING

- Continue genetic monitoring in all populations
- Periodically revise estimates of genetic diversity

and genetic effective population size
- Detect and track immigration, inbreeding, and admixture

Declines in genetic diversity from historical levels are well documented in SNRF populations (e.g., Perrine et al. 2007; Sacks et al. 2010a; Statham et al. 2012b; Quinn 2017, Quinn et al. 2019; Quinn et al. in review). Continued genetic monitoring is important to detect variation in genetic diversity and genetic effective population size, and can also help to track the rate and prevalence of immigration, inbreeding, and admixture in each population. These metrics can provide insight into whether management interventions (such as translocations) are necessary to relieve inbreeding or outbreeding depression.

Noninvasive collection of scats during snow-free months is the most efficient approach to genetic monitoring, and can be combined efficiently with scat collection for demographic monitoring. In order to meet both objectives, a balance between intensity and distribution of sampling effort can be achieved by surveying a focal area of each population on an annual basis to enable repeated demographic estimates, along with opportunistic sampling over a broader spatial scale for use in genetic assessments. Tissue or blood samples are also invaluable, enabling high-resolution genomic analyses that cannot be performed using scat or hair samples, and should be collected whenever possible.

#### III.B.1.1.4. POTENTIAL SOURCE POPULATIONS

- Identify potential source populations
- Estimate abundance
- Assess disease status
- Assess genetic diversity
- Evaluate population viability with removals
- Develop thresholds for population metrics at which populations are considered appropriate and robust enough to provide source stock

Translocation planning requires the identification of suitable source populations that are genetically, phenotypically, and behaviorally compatible with SNRF, are sufficiently abundant and genetically diverse to withstand removals, and contain individuals that do not pose a novel disease threat to the recipient area (IUCN 2013). For populations that may be under consideration as potential source stock, it is critical to develop abundance estimates, assess disease status and genetic diversity, and evaluate population viability under a variety of removal scenarios. In some populations, current data may be sufficient to determine suitability for translocation stock; in others, increased monitoring intensity may be necessary. Additional phenotypic and genomic data would also enable more precise evaluation of potential sources' compatibility with SNRF.

In addition to evaluating each potential source population separately, managers should develop thresholds at which population size, genetic diversity, and genetic or phenotypic similarity are considered sufficient for a population to provide source stock.

### III.B.1.2. EXTENSIVE TIER 1 INFORMATION NEEDS

#### III.B.1.2.1. PRESENCE, ABSENCE, AND EXPANSION

- Conduct presence/absence surveys in areas of the historical range where SNRF have not been detected (high-elevation regions [above 2,500 m] of the southern Sierra Nevada [Green et al. in preparation; Stermer in preparation]

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[5] Goal 1. Identify and complete research, analysis, and monitoring needed to resolve uncertainties and inform management interventions.

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[10] See section III.C.2.1.6.c. Rocky Mountain Red Foxes.

and unsurveyed areas of the Oregon Cascades including south of CLNP, between CLNP and the Central Cascades study area, and between the Central Cascades study area and Mt. Hood)
- Conduct surveys in potential habitat adjacent to occupied areas to detect potential population expansion

Vast areas of the historical range currently remain unsurveyed for SNRF or have not been surveyed in decades. Given recent SNRF detections in areas previously thought to be unoccupied, it is necessary to substantially increase survey efforts, particularly in unsurveyed areas of the historical range, to determine the subspecies' current distribution. Extensive surveys are critical to detect undiscovered populations, while surveys at the periphery of occupied habitat can reveal range expansion and dispersal.

Appendix B presents a framework to guide survey and monitoring efforts according to methods that have been found most effective for SNRF. For surveys of remote locations not known to be occupied by SNRF, baited remote cameras perform well at detecting SNRF in winter, whereas scat surveys and passive, unbaited remote cameras can be employed concurrently to detect SNRF in summer. Specific methods for deploying remote cameras vary by region and habitat type. While we do not provide detailed protocols in this document, we discuss general considerations for survey and monitoring methods in Appendix B. Once red foxes are detected by remote camera, subsequent efforts should include collection of genetic material to determine subspecies and individual identities. Scat surveys are the most reliable means of obtaining genetic samples as they are less susceptible than baited hair snares to bias associated with individual behavioral variability.

The development of distribution models from presence/absence data has proven useful in prioritizing survey locations (Cleve et al. 2011; Statham et al. 2012b; Poisson et al. 2019; Quinn et al. 2018; Green et al. in preparation; Stermer in preparation), and survey data can be used to update distribution models periodically. Such models can also be used to compare the probability of detecting SNRF by different methods (e.g., winter vs. summer remote camera surveys, remote cameras vs. scat surveys, human vs. detection dog for scat surveys; Green et al. in preparation) and quantify the amount of effort needed to accurately determine SNRF presence. Future survey efforts should be guided by distribution models developed from the most accurate and recent data. Currently, priority survey areas include unsurveyed high-elevation regions (above 2,500 m) of the southern Sierra Nevada (Green et al. in preparation; Stermer in preparation), and areas of the Oregon Cascades where SNRF have not been detected, including south of CLNP, between CLNP and the Central Cascades study area, and between the Central Cascades study area and Mt. Hood. As discussed above, remote cameras and scat surveys can provide data for multiple inquiries in addition to SNRF distribution studies.

Importantly, failure to detect SNRF does not prove their absence. Before any area is considered unoccupied by SNRF, a threshold must be established at which repeated surveys without detections are deemed to constitute sufficient evidence for absence. Moreover, accounting for potentially expanding populations necessitates periodic resurveys of all suitable habitat regardless of prior results.

## III.B.2. TIER 2: SNRF ECOLOGY AND POTENTIAL THREATS

Tier 2 Information Needs presented here are not ranked by priority or urgency, but are presented in the order of the potential threats they address[6]. Some Tier 2 Information Needs may require dedicated research efforts, whereas others may be addressed concurrently with Tier 1 studies of extant populations.

### III.B.2.1. VEHICLE STRIKES

- Identify specific areas where SNRF cross roads. Document locations where SNRF or other wildlife are struck by vehicles
- Assess efficacy of methods (e.g., road signs, speedbumps) to alert visitors to wildlife crossing areas and encourage slower traffic patterns
- Evaluate success of wildlife crossing structures implemented in other locations for similar species

Several SNRF have been killed by vehicle strikes in the Central Cascades study area in Oregon (J. Bowles, ODFW, personal communication 2019). Vehicle strikes have also killed SNRF in the CLNP study area in Oregon and the Sonora Pass study area in California. It is possible that mortalities associated with vehicle strikes occur but are not reported in areas where SNRF habitat intersects roads elsewhere in Oregon and California. With more information about the frequency and locations of vehicle strikes, a number of management interventions could be considered, ranging from posting signs on roadways, to reducing speed limits, to constructing wildlife crossing structures. While information is lacking about specific wildlife crossing structures shown to be effective in reducing vehicle strike mortality for foxes, red foxes are known to use overpasses, underpasses, and culverts (Rodríguez et al. 1997; Craveiro et al. 2019; Asari et al. 2020), and studies suggest that many carnivores select crossing structures with more vegetative cover and in areas with less human presence (Rodríguez et al. 1997; Glista et al. 2009). These efforts may be more readily implemented in areas where vehicle strikes consistently cause mortalities of multiple species.

Mortalities of collared animals and reports of vehicle strikes should be investigated promptly to determine cause and location of death. Movement data from GPS-collared individuals could help identify crossing locations. Roadkill surveys could be distributed to the public to generate information about the frequency and location of vehicle strikes. State Departments of Transportation should be consulted regarding the feasibility of implementing signage, reduced speed limits, or wildlife crossings in areas of concern.

### III.B.2.2. LOCAL ADAPTATIONS OF THE SNRF GENOME

- Continue to collect morphological and phenological data from SNRF and other red fox populations

Identifying local adaptations of the SNRF genome is an important step in assessing the potential risk of outbreeding depression. If the threat of outbreeding depression due to gene flow from non-montane-adapted lineages is considered sufficiently high, it could be mitigated through translocations from other montane populations sharing local adaptations. Collecting more data on morphology, timing of reproduction, and litter sizes in SNRF and other red fox populations could enable statistical comparisons of phenotypic differences among populations and subspecies.

### III.B.2.3. HABITAT ASSOCIATIONS

- Investigate home-range size and composition, fine-scale habitat selection, seasonal habitat use, and den-site selection.
- Evaluate existing habitat connectivity for SNRF and assess the potential for habitat fragmentation. Identify barriers to connectivity or colonization
- Determine what factors influence denning success and at what distance from den sites. Use this information to estimate reasonable buffers to protect SNRF den sites from disturbance or loss of critical habitat characteristics

#### III.B.2.3.1. CLIMATE CHANGE

- Determine fine-scale characteristics that affect

habitat suitability for SNRF in each region and model effects of climate change on those characteristics
- Identify habitat associations of SNRF using atypical environments
- Identify potential climate refugia for SNRF
- Assess effects of large-scale wildfires on SNRF habitat characteristics and space use

Climate change is expected to alter SNRF habitat in California and Oregon due to rising temperatures and decreasing snowpacks (Dettinger et al. 2018; Mote et al. 2019). Climate change may also have indirect negative effects on SNRF by facilitating greater abundance of gray foxes and coyotes in SNRF habitat or affecting the abundance and distribution of prey species. Research is needed to describe typical SNRF habitat associations in each region, understand SNRF space use in occupied areas with atypical habitat (e.g., the Caribou Wilderness near LVNP), characterize den-site selection, and identify potential climate refugia. Translocation efforts could seek to mitigate the likely limiting effects of climate change by prioritizing SNRF translocations into unoccupied areas with extensive and varied high-elevation habitat.

### III.B.2.3.2. LAND USE AND MANAGEMENT

- Determine fine-scale characteristics that affect habitat suitability or quality for SNRF, and identify land management activities that could create, alter, or preserve these characteristics
- Investigate the influence of land management activities (e.g., timber harvest, prescribed fire, grazing) on SNRF presence or habitat selection
- Identify land use and management activities that affect denning behavior and den-site selection and determine appropriate timing and distance from den sites for such activities

Little is known about fine-scale habitat selection or den-site selection in SNRF, although some data have been collected recently and analyses are forthcoming. Current land uses such as grazing, silvicultural treatments, prescribed fire, and recreation may have positive, negative, or neutral impacts on habitat conditions selected for by SNRF or their prey. A better understanding of any such impacts could lead to adjustments in management prescriptions to preserve important attributes of SNRF habitat.

### III.B.2.4. INTERACTIONS WITH SYMPATRIC CARNIVORES

- Estimate density, abundance, and distribution of sympatric carnivores. Identify seasonal and long-term changes in these parameters (e.g., elevational shifts in species distribution with climate change; density of other carnivores in SNRF habitat in winter vs. summer)
- Identify diet niche width and overlap for SNRF and sympatric carnivores, particularly in winter
- Determine whether sympatric carnivores limit SNRF distribution. Assess variation in activity patterns (e.g., temporal or spatial partitioning) or occupancy of SNRF in the presence of other carnivores
- Identify direct (e.g., predation) and indirect (e.g., competition for prey or habitat, disease transmission) impacts of sympatric carnivores on SNRF fitness

Interactions with sympatric carnivores could have fitness consequences for SNRF through competitive exclusion or aggressive interference. Coyotes, martens, gray foxes, bobcats, fishers, and other carnivores (including other subspecies of red fox that may have overlapping distributions) may compete with SNRF for prey. Conversely, carrion from prey killed by larger carnivore species could provide

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[6] See section III.A. Potential Threats.

a food source for SNRF, especially during winter. Interactions with coyotes and gray foxes likely present the greatest potential conservation concern for SNRF. While few feasible management options may be available to mitigate such interactions, understanding competitive relationships is important to identify factors that may limit or negatively affect SNRF populations.

Assessing potential aggressive or competitive relationships with other carnivores involves multiple study objectives. Relative abundance among species could be studied through noninvasive genetic means. Similarly, overlap in diet could be determined through stable isotopes or morphological and metagenomic analysis of scats (e.g., Perrine 2005; Poisson et al. 2019). Carnivore presence in SNRF habitat can also be documented via remote cameras, though these data may not provide reliable information about abundance. Using GPS collars to monitor individual sympatric carnivores and SNRF could document the extent of carnivore movements in SNRF habitat and could potentially reveal carnivore predation on SNRF or whether other carnivores disturb dens used by SNRF.

## III.B.2.5. RECREATION EFFECTS

- Implement recreation intensity studies to compare recreation use data (e.g., GPS tracks from recreationists) to location data from collared SNRF. Identify areas and timing of overlap and determine whether patterns of space use in SNRF appear to be influenced by type, timing, or intensity of recreation use
- Locate SNRF dens and assess their proximity to recreation activities
- Assess the level of habituation in each SNRF population or study area. Record instances of apparent habituation and estimate the number of habituated individuals
- Identify sources and amounts of anthropogenic food or trash available to SNRF and determine the main vectors for habituation (e.g., parking lots, campgrounds, resorts, backcountry use areas). In areas where habituation has been documented, assess the efficacy of current methods for collecting, storing, and removing anthropogenic food or trash
- Evaluate success of methods used to deter or relocate habituated SNRF or similar species
- Document interactions between domestic dogs and SNRF or other wildlife

SNRF likely alter their behavior in response to human presence in their habitat, either by becoming habituated or by avoiding humans. This behavioral response may vary by individual SNRF and by recreation type (e.g., motorized vs. non-motorized, dispersed vs. concentrated), timing (season, time of day), and intensity or duration of use. Recreation may also have population-level consequences for SNRF by causing direct mortality (e.g., vehicle strikes, diseases transmitted by pets), inducing SNRF to abandon optimal habitat, or facilitating increased competition with other carnivores. It is also possible that recreation does not affect SNRF fitness. A better understanding of how recreation impacts SNRF could guide appropriate management responses and inform public education efforts.

Existing data on the effects of recreation on SNRF behavior are limited to observations of individual habituated foxes and are insufficient to support hypotheses about behavioral modifications linked to recreational activities. New studies specifically designed to investigate these effects, such as those conducted on Canada lynx by Olson et al. (2018) and on wolverines by Heinemeyer et al. (2018), would be necessary to draw conclusions. Such studies would likely require fine-scale recreation-use data as well as movement data from an adequate sample of GPS-collared foxes.

Motorized recreation occurring in SNRF habitat, such as the use of OSVs and other off-highway vehicles (OHVs) or all-terrain vehicles (ATVs), may be of particular interest. The effects of motorized recreation on foxes are not well studied, but Fuglei et al. (2017) found that Arctic foxes changed their activity patterns in an area with high OSV use. The prevalence and behavior of unleashed domestic or feral dogs in SNRF habitat may also merit study; 1 SNRF in the Lassen population was killed by a dog in 2002 (Perrine 2005) and unleashed dogs are frequently detected by remote cameras in the Caribou Wilderness (CDFW, unpublished data). Dogs are prohibited in many undeveloped areas of National Parks, but are permitted and not required to be leashed on National Forest lands, and are often observed in areas occupied by SNRF in the Central Cascades, CLNP, and Sonora Pass study areas (J. Bowles, ODFW, personal communication 2020; S. Mohren, NPS, personal communication 2020; A. Orlando and K. Boatner, USFS, personal communication 2020).

Because recreational activities and their intensities vary by region, results would be narrowly applicable to the region studied, unless research was able to establish effects above some threshold level of intensity by type. Some evidence also points to substantial behavioral variation among individual foxes, suggesting that even within a single region, a large sample size encapsulating that variation would be necessary to be considered representative.

### III.B.2.6. FOOD SOURCES AND AVAILABILITY

- Perform diet analysis (e.g., metagenomic or stable isotope analysis) of scat and hair samples collected during ongoing monitoring
- Determine reliance of SNRF on leporid prey, particularly in winter. Estimate occupancy and abundance of leporids in SNRF habitat and quantify any impacts of RHDV-2
- Determine SNRF use of or reliance on carrion killed by other carnivores
- Document the prevalence of anthropogenic food or trash in the diet of habituated SNRF and identify possible sources

We have only a partial understanding of the primary components of the SNRF diet or the abundance of those food items in SNRF habitat. Furthermore, only a small proportion of available data on diet items comes from the winter and spring months. Limited food availability, particularly during winter and spring, could result in lower reproductive rates and neonatal survival, as well as reduced health and fitness in all age classes.

The most efficient method of determining diet composition is through metagenomic analysis of scat and stable isotope analysis of hair samples. Diet studies would be most informative if focused on the winter and spring, when energetic requirements are the highest and prey likely the scarcest, though scat collection and surveys for prey species would be more challenging during months with high snow depths. Abundance and density of prey species could be estimated through transect surveys or capturing and marking prey items, but would likely require dedicated study that is independent of other research questions. In particular, a hypothesis in need of investigation is whether snowshoe hares and, in the Sierra Nevada, white-tailed jackrabbits represent critical winter prey resources for SNRF. A related question is how reproductive success of SNRF relates to leporid abundance the previous winter. Understanding the current ranges, population dynamics, and population status of these prey species is also important to determine the extent to which leporid abundance may be relevant to SNRF population growth rates.

Red foxes throughout the world are known to pursue anthropogenic food sources (Tsukada 1997; Contesse et al. 2004; Reese 2007; Stickney et al. 2014), and SNRF in more developed areas may become habituated to anthropogenic food or trash. Begging foxes have been documented in the Lassen (Perrine and Arnold 2001; Perrine 2005), Sonora Pass (USFS, unpublished data), Central Cascades (J. Bowles, ODFW, personal communication 2019), and CLNP study areas (S. Mohren, NPS, personal communication 2019). Diet analysis, in conjunction with behavioral studies as described under III.B.2.5. Recreation Effects above, could help determine the prevalence and impacts of SNRF habituation to anthropogenic food or trash. Measures to curtail SNRF reliance on anthropogenic food could include public education to limit intentional feeding, installation of carnivore-proof trash receptacles, or increased enforcement of proper trash disposal in SNRF habitat.

## III.B.2.7. PRESENCE OF DISEASES

- Collect biological samples (e.g., blood, feces, respiratory secretions, ectoparasites) from all captured or necropsied SNRF for disease and parasite surveillance. Conduct histology, PCR, serology, and toxicology testing
- Perform physical exams to assess body condition of all captured SNRF, including reproductive status for females
- Perform full necropsies on all SNRF mortalities whenever carcass condition is suitable
- Consider surveillance for parvovirus and parasites as part of scat collection efforts
- Test sympatric carnivores for infection and exposure to diseases of conservation concern through necropsy of fresh mortalities or by-catch of live animals

We have no evidence of diseases in SNRF, but systematic monitoring for the presence of diseases has not occurred and diseases may be present but undetected. Highly virulent diseases may have population-levels effects on SNRF, and regular monitoring is crucial to enable detection of diseases and management intervention, if warranted. Information about diseases in potential source and recipient populations is also an essential precursor to any translocation effort.

Some disease surveillance can be carried out noninvasively by collecting and testing fecal samples for parasites or viruses shed via the fecal route. Studies that involve capture of SNRF should collect biological samples for disease surveillance, and testing of samples should be coordinated between Oregon and California so that results are comparable across the species' range. Mortalities of collared SNRF or opportunistically collected SNRF carcasess should be necropsied as soon as possible to determine cause of death and collect biological samples.

In addition to their value in detecting and perhaps preventing devastating disease outbreaks in SNRF, biological sample collection and cause-specific mortality data could be widely applicable, providing insight into general body condition, diet, levels of stress hormones, exposure to toxins and pathogens, morphology, and genetics. These data would be useful to compare to the larger datasets associated with other non-montane subspecies of North American red foxes. Biological samples from captured SNRF or mortalities could also enable genomic analysis not possible with noninvasive genetic samples.

## III.B.2.8. HUNTING AND TRAPPING

- Determine the number of SNRF harvested annually and the proportion this harvest represents of the total SNRF population in Oregon

The current level of harvest in the Oregon SNRF range is not known to be, or considered by ODFW to be, a threat to the persistence of SNRF in the state. All licensed furtakers in Oregon are required to report their activities annually, including species and number of individuals harvested, county, activity type (e.g., hunting vs. trapping), effort, and non-harvest (e.g., number observed or captured but not harvested). In addition to harvest numbers, these reports allow ODFW to monitor effort, intent, and incidental captures, and to contact individual licensed furtakers to solicit their potential engagement in research efforts. Regular communication with licensed furtakers or hunting and trapping organizations could include requesting submission of samples (e.g., hair, tooth, tissue) from harvested red foxes to enable estimation of the relative proportions of each subspecies harvested, as well as sex and age of harvested foxes. This information could be monitored over time to document any changes to harvest levels that might result in impacts to the SNRF. ODFW will continue to monitor harvest data for red foxes, but the development of population estimates for SNRF in the state may be desirable to estimate what proportion of the population is harvested, as well as to meet other information needs.

## III.B.3. ADDITIONAL INFORMATION NEEDS

### III.B.3.1. IMPROVED TECHNOLOGY AND ACCESS TO RESOURCES

Studies of SNRF are hindered in many ways by limited resources such as deficient collar technology (e.g., battery failure, premature cessation of data logging or reporting), funding and staffing constraints, and reliance on time-consuming manual processes for tasks such as organizing digital image data. SNRF researchers could benefit greatly from identification of technological advances, funding sources, and time-saving technologies relevant to their study objectives, such as:

- Tools to facilitate information sharing among researchers and pooling of experience with different technologies, methods, and protocols
- Frequent review of relevant literature and grant opportunities
- Comparative modeling of method efficiency and effectiveness
- Unified methodology across research groups when feasible
- Streamlined protocols for storing and sharing data
- Shared resources for training staff
- Consultation with outside experts (modelers, collar manufacturers, data analysts, software engineers, etc.)
- Support at all levels of management for ongoing collaboration between federal, state, non-profit, and academic partners

## III.C. MANAGEMENT ACTIONS

Possible management actions to achieve the conservation vision for the SNRF fall into 3 tiers based on need, benefit, risk, and feasibility. Until we better understand the status of each SNRF population and the threats they face, we recommend the immediate implementation only of Tier 1 actions—those that may be beneficial to the SNRF and do not entail any potential risk of individual mortality or decline in vital rates. Tier 2 actions are translocations that will likely be critical to realizing the conservation vision for the SNRF, but cannot be implemented effectively without more information and collaborative planning. Gathering the information that would enable managers to determine which translocation actions are necessary to recover the subspecies, and to design and implement such translocations, is highlighted in this document both as a vital information need and as an urgent next step in conservation planning. Tier 3 actions are those for which we have no evidence of current need, but which may be considered if that evidence emerges in the future. Actions described under III.C.4. Other Actions are not presently justified and may or may not be feasible even if future evidence points to a need.

Research and monitoring efforts are of the greatest urgency to fill the knowledge gaps identified in section III.B. Information Needs, and are key to any further management recommendations.

## III.C.1. TIER 1

*Management actions that may be beneficial to* *the SNRF and do not entail any potential risk of individual mortality or decline in vital rates*

## III.C.1.1. PUBLIC EDUCATION

Despite outreach by CDFW, ODFW, NPS, USFS, and others, conservation concerns about the SNRF are not well known to the general public. In addition to building popular support and enthusiasm for SNRF conservation, public education can mitigate potential threats to the SNRF by promoting respectful behavior by humans using SNRF habitat. Throughout the historical range in California and Oregon, we recommend the following measures:

- Discourage feeding SNRF or making trash available to scavenging SNRF or other sympatric carnivores such as black bears, coyotes, or gray foxes. Provide carnivore-proof trash receptacles at developed recreation sites within SNRF habitat, particularly in winter and in locations where trash can accumulate, such as parking lots and campgrounds.
- Encourage pet owners to prevent pet aggression toward SNRF and minimize potential disease transmission by leashing pets, removing pet waste, and ensuring pets are vaccinated for common diseases such as rabies and canine distemper.
- Discourage use of rodenticides at resorts, residences, and grazing leases in occupied SNRF habitat.
- Continue to provide and improve general educational materials about SNRF for the public and the media.
- Continue to engage the public in citizen science efforts to monitor SNRF, including by encouraging reporting of observations to appropriate managers and submission of photos if available to confirm identification.

These management actions would contribute to meeting Objective 2.c ("Maintain the functional role, natural ecology, and behavior of SNRF") and Goal 4 of this Strategy ("Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation").

## III.C.1.2. VEHICLE STRIKE MITIGATION

Vehicle strikes are a significant cause of mortality for wildlife populations worldwide (Hill et al 2019; Schwartz et al. 2020), and are one of the only documented sources of mortality for SNRF. Along the Cascade Lakes Scenic Byway near Mt. Bachelor in Oregon, the frequency of SNRF struck and killed by vehicles may be increasing, and vehicle strikes kill juveniles as well as adults. One SNRF was also struck and killed by a vehicle on Munson Valley Road in CLNP in 2013, and another on Highway 108 near Sonora Pass in 2011. We recommend that managers consider the following measures in areas where vehicles have struck wildlife, and in particular where busy roads intersect occupied SNRF habitat (e.g., Cascade Lakes Scenic Byway near Mt. Bachelor, CLNP, LVNP, Sonora Pass, Tioga Pass):

- Identify known crossings of SNRF (or other wildlife)
- Install signage to notify motorists of known wildlife crossings
- Reduce speed limits in the vicinity of known wildlife crossings
- At known wildlife crossings, construct wildlife over- or underpasses, enlarge culverts, or replace existing small culverts with larger culverts that would facilitate use by more species
- Maintain vegetative cover in the vicinity of culverts and over- or underpasses
- Install fencing to guide wildlife toward culverts and over- or underpasses

While information is lacking about specific road crossing structures shown to be effective in reducing vehicle strike mortality for foxes, red foxes are known to use overpasses, underpasses, and culverts (Rodríguez et al. 1997; Craveiro et al. 2019; Asari et al. 2020), and studies suggest that many carnivores select crossing structures with more vegetative cover and in areas with less human presence (Rodríguez et al. 1997; Glista et al. 2009).

These actions would have the potential to protect multiple wildlife species from additive mortality due to vehicle strikes, and would contribute to meeting Goal 3 ("Mitigate individual- and population-level threats to SNRF") and Goal 4 ("Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation") of this Strategy.

Vehicle strikes may occur but go unreported along highways in occupied SNRF habitat in California and Oregon. Public education to improve reporting of vehicle strikes may help to identify additional locations where signage or crossing structures could mitigate any threat to SNRF. Roadkill surveys could be distributed to the public to generate information about the frequency and location of vehicle strikes. If SNRF are struck and killed by vehicles, the carcasses should be collected for genetic and disease analysis.

## III.C.1.3. RECREATION MANAGEMENT

We do not know to what extent recreation within SNRF habitat[7] may impact SNRF populations. We can assume, however, that measures to protect SNRF habitat from increased human disturbance and SNRF individuals from habituation to humans would be beneficial for all populations of SNRF, without creating undue burdens for recreationists or land managers. In addition to the public education strategies enumerated above, wherever SNRF and human use co-occur, we recommend that managers:

- Consider the potential impacts to SNRF when permitting new recreation uses or development in SNRF habitats. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3. Rodenticides, and III.A.7. Recreation, Habituation, and Development. If feasible, minimize new recreational uses or developments, such as roads, trails, parking lots, campgrounds, resorts, and OHV or OSV areas, that would result in substantially increased human or motor vehicle presence in areas used by SNRF.
- Where a den site is identified, coordinate with wildlife managers to assess potential impacts of recreation activities in that vicinity. Because data on active den sites are too limited currently to inform estimates of the area that constitutes the vicinity of a den, land and wildlife managers should work together to determine an appropriate buffer, keeping in mind that SNRF may use more than 1 den site during the period of pup dependency and may travel relatively long distances away from den sites. When issuing special use permits for events in SNRF habitat, consider the location, size, and timing of events relative to known SNRF den sites and the period of increased vulnerability during denning season (at minimum, late pregnancy through the pre-weaning period, roughly April 1–August 1), as well as whether events will likely introduce anthropogenic food or trash into SNRF habitat.
- Protect sensitive location data, especially den site locations, from public knowledge.

These actions would contribute to meeting Objective 2.c ("Maintain the functional role, natural ecology, and behavior of SNRF"), Objective 2.d ("Maintain or increase the quality of available habitat"), Goal 3 ("Mitigate individual- and population-level threats to SNRF"), and Goal 4 ("Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation") of this Strategy.

## III.C.1.4. LAND MANAGEMENT

Because the impacts of land management activities in SNRF habitat[8] are uncertain, it is not appropriate to specify detailed project design criteria for activities in SNRF habitat. In the absence of more fine-scale information about SNRF habitat selection, we recommend that managers working in SNRF habitat seek to maintain healthy, functioning alpine, subalpine, and montane environments and small mammal populations within their natural ranges of variation. Current land management prescriptions that are designed to meet these goals are likely sufficient to preserve desirable habitat for SNRF, particularly those that take into account the predicted future effects of climate change on these high-elevation environments.

### III.C.1.4.1. CONNECTIVITY AND FRAGMENTATION

- Consider the potential impacts to SNRF when planning or permitting road construction or expansion or other land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3.Rodenticides, and III.A.12. Land Use and Management. If feasible, minimize land uses or developments that would result in substantially increased human or motor vehicle presence in SNRF habitat.

### III.C.1.4.2. PREY HABITAT AND FOOD SOURCES

- Consider the potential impacts to small mammal prey species, particularly leporids, when planning or permitting land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in section III.A.12. Land Use and Management, and include loss of habitat due to removal of forest understory structure or to tree and shrub encroachment in meadow habitats.
- Maintain or enhance meadows in SNRF habitat within their natural range of variation, preserving hydrologic function and plant species composition.
- Silvicultural treatments must be viewed within the broader context of forest management, in which they play a necessary role. Impacts to small mammal populations must be weighed against numerous other factors, such as wildfire risks to human communities at the wildland-urban interface. To the extent consistent with fuels reduction, vegetation treatment, and thinning activities necessary for forest health and fire risk reduction, maintain elements of understory structure in forested SNRF habitats to provide cover for forest-floor-dwelling small mammal species.
- Maintain subalpine and montane forests in SNRF habitat within their natural range of variation to support the health of mast species such as whitebark pine, which provide food for a variety of wildlife species (Keane et al. 2012).

### III.C.1.4.3. DEN SITES

- When a den site is identified, coordinate with wildlife managers to determine appropriate land use or management activities in that vicinity. Because data on active den sites are too limited currently to inform estimates of the area that constitutes the vicinity of a den, land and wildlife managers should work together to determine an appropriate buffer, keeping in mind that SNRF may use more than 1 den site during the period of pup dependency and may travel relatively long distances away from den sites. Consider the location, size, and timing of land use or management activities relative to known SNRF den sites and the period of increased vulnerability during denning season

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[7] For the purposes of these and other recommendations pertaining to land management, "SNRF habitat" is defined as areas known to be occupied by SNRF (i.e., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the historical range (e.g., Green et al. in preparation; Stermer in preparation).

(at minimum, late pregnancy through the pre-weaning period, roughly April 1–August 1), as well as whether the activities will likely introduce anthropogenic food or trash into SNRF habitat.

As we learn more about SNRF habitat selection and small mammal populations, we encourage managers to continue to periodically reevaluate current management prescriptions (e.g., for grazing, timber harvest, fuels reduction, vegetation treatments, road and trail building, special use permits, etc.) to ensure they provide adequate protection for SNRF habitat characteristics as we understand them, as well as for habitat characteristics selected for by SNRF prey species, particularly leporids.

These measures would contribute to meeting Objective 2.d ("Maintain or increase the quality of available habitat") and Goal 3 ("Mitigate individual- and population-level threats to SNRF") of this Strategy.

### III.C.1.5. HARVEST REPORTING

Hunting and trapping of SNRF are prohibited in California, and have been since 1974. While hunting and trapping in Oregon result in a very low level of red fox mortality and are not considered by ODFW to be threats to the SNRF (because of low harvest levels and limited furtaker activity within SNRF habitat), we do not know how many red foxes harvested annually are SNRF because trapped red foxes are not identified by subspecies. If feasible to implement, a program requesting that licensed furtakers submit red fox samples for genetic testing would enable managers to quantify and monitor harvest of SNRF in Oregon. Location information for samples would also add to our knowledge of the distribution of SNRF and other red fox subspecies.

This information would contribute to meeting Goal 1 ("Identify, secure funding for, and complete research, analysis, and monitoring needed to address uncertainties and inform management interventions") of this Strategy.

## III.C.2. TIER 2

*Management actions that may be beneficial but pose potential risks to the SNRF and require more information prior to implementation*

### III.C.2.1. TRANSLOCATIONS

A common dilemma in conservation biology arises from the need to balance the urgency of an action with uncertainty about its consequences. Delaying management intervention until its outcomes are well understood can minimize risks, but such a delay can also diminish a species' chances of survival. While a formal translocation feasibility assessment is beyond the scope of this Strategy, such an assessment should be undertaken as soon as possible (see section III.D.2. Planning and Collaboration: Translocation Feasibility Assessment). To inform future translocation planning, below we explore the potential costs and benefits to the SNRF of a series of translocation scenarios. We consider each in the context of our current level of knowledge and identify the critical information gaps that, if filled, could tip the scales toward a recommendation to act.

*Translocation* refers generally to the capture, transport, and release of animals. We use the term *reinforcement* to denote the addition of individuals to an extant population, and *reintroduction* to mean establishing a new population in an area of

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[8] For the purposes of these and other recommendations pertaining to land management, "SNRF habitat" is defined as areas known to be occupied by SNRF (i.e., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the historical range (e.g., Green et al. in preparation; Stermer in preparation).

the historical range determined to be unoccupied (IUCN 2013).

## III.C.2.1.1. LASSEN: REINFORCEMENT

### III.C.2.1.1.A. POTENTIAL CONSERVATION BENEFITS

All available evidence indicates that the Lassen population is very small and suffers from low genetic diversity and inbreeding. Notwithstanding a single documented immigration event in 2011, Lassen SNRF are isolated, with no apparent recent connectivity to other known SNRF populations. Since the 2011 immigration event, all known breeding has been between close relatives. Reinforcement is likely necessary to introduce novel genetic material and disrupt inbreeding, enabling the Lassen population to increase in size and resiliency.

### III.C.2.1.1.B. POTENTIAL RISKS

What caused the Lassen population to decline, and why has it remained small? We do not have a complete understanding of the historical or contemporary dangers affecting the population and we cannot rule out the possibility that translocated foxes would succumb to an unknown threat. However, the relatively long lifespans (greater than 5 years) documented for several Lassen individuals suggest that adult survival is not limiting the population (Carlson et al. 2019).

Reinforcement translocations to the Lassen population would need to be carefully planned to avoid increased genetic load, swamping, or replacement of the native genome. Swamping, or the loss of locally adapted alleles due to introgression, is a concern when the recipient population is very small and has a reproductive disadvantage (i.e., from inbreeding depression). The low genetic diversity of very small populations also means that the genome typically contains a low proportion of deleterious alleles. Larger populations, in addition to higher levels of favorable genetic diversity, also carry higher proportions of deleterious alleles. Reinforcing a very small population like Lassen with individuals from a larger population could introduce detrimental as well as beneficial genetic material.

There is substantially less high-elevation subalpine and alpine habitat available in the Lassen Peak region in comparison to the Sierra Nevada region, and the actual carrying capacity of the environment is unknown. The Lassen Peak region may only be able to support a small population of SNRF. Still, historical sources point to a broader area of occupied habitat than the current distribution, indicating that some range expansion is possible.

### III.C.2.1.1.C. INFORMATION NEEDS

Further analysis is needed to determine the ideal number of individuals and sex ratio for a reinforcement of the Lassen population, and whether successive translocations might be necessary over a period of years to sustain a reinforced population. An appropriate source population has not yet been identified, though several possibilities are discussed below.

Continued monitoring is essential to understanding the trajectory of the Lassen population, as well as identifying causes of mortality and estimating vital rates.

## III.C.2.1.2. SIERRA NEVADA: REINFORCEMENT

### III.C.2.1.2.A. POTENTIAL CONSERVATION BENEFITS

While Quinn et al. (2019) found strong evidence for inbreeding depression in the Sonora Pass study area of the Sierra Nevada population, its effects seem to have been alleviated in the short term by the arrival of immigrant foxes. If additional genetic rescue is needed, reinforcing the population in the

Sonora Pass study area could accomplish that goal. If outbreeding with Great Basin red foxes reduces the frequency of locally adaptive genes within the Sierra Nevada population over time, reinforcement from montane source populations could potentially counter the effects of outbreeding by increasing the proportion of montane-adapted genes in the population. Moreover, whereas the population in the Sonora Pass study area appears to be growing and has some level of connectivity with the YNP and Mono Creek study areas, the population is still small and could potentially benefit both demographically and genetically from additional individuals.

#### III.C.2.1.2.B. POTENTIAL RISKS

As at Lassen, we know very little about what threats affect the Sierra Nevada population in the Sonora Pass study area or may impact individuals translocated there or elsewhere in the Sierra Nevada. Because the known population is still small, reinforcement with non-SNRF stock would also carry a risk of genetic swamping or increased genetic load. These risks could be mitigated by sourcing red foxes from another montane subspecies if no other SNRF population was deemed large enough to serve as a donor population.

#### III.C.2.1.2.C. INFORMATION NEEDS

Continued study in the YNP, Mono Creek, and Ritter Range study areas is necessary to determine whether detections in those areas represent expansions of the population in the Sonora Pass study area. If the population in the Sonora Pass study area grows large quickly enough or establishes connectivity with other SNRF populations that may exist elsewhere in the Sierra Nevada, both inbreeding and outbreeding may diminish as potential threats. Assumptions about the threats of genetic swamping and outbreeding depression in the Sierra Nevada population depend on a) the capacity of the population to grow and b) whether and at what rate gene flow with Great Basin red foxes continues. Sustained genetic monitoring can enable detection of future immigrants, as well as furthering our understanding of genetic and demographic trends in the Sonora Pass study area.

The specific details of a translocation to the Sierra Nevada (number of individuals, identity of source population, etc.) would require further analyses. An appropriate source population has not yet been identified, though several possibilities are discussed below.

### III.C.2.1.3. SIERRA NEVADA: REINTRODUCTIONS

#### III.C.2.1.3.A. POTENTIAL CONSERVATION BENEFITS

Ample high-elevation habitat exists throughout the Sierra Nevada (Cleve et al. 2011; Green et al. in preparation; Stermer in preparation), though much of it has not been adequately surveyed for SNRF presence. If SNRF are determined to be absent from areas of their historical range in the Sierra Nevada, reintroductions to those areas could approximate historical metapopulation structure. Reintroductions adjacent to established populations could maximize the potential for connectivity.

#### III.C.2.1.3.B. POTENTIAL RISKS

SNRF individuals or populations may be present even where they have not been detected. If reintroductions took place in an area where SNRF persist, aggression or competition could occur between resident and reintroduced foxes. Newly reintroduced populations could become isolated or extirpated, and if managers are not highly confident in the potential for connectivity, reintroductions might require more individuals to reduce the risk of inbreeding within a reintroduced population. Unknown threats may also pose risks to SNRF in areas that are currently unoccupied.

#### III.C.2.1.3.C. INFORMATION NEEDS

Surveys where SNRF have not yet been detected in the Sierra Nevada are critical before reintroductions are considered, and may also lead to the discovery of previously undetected populations or individuals with potential connectivity to SNRF in the Sonora Pass study area. Criteria for presuming absence must be developed before any area is considered unoccupied by SNRF.

Analysis is needed to determine the ideal number of individuals and sex ratio for reintroductions to unoccupied areas of the Sierra Nevada, as well as whether successive translocations might be necessary over a period of years to sustain a reintroduced population. An appropriate source population has not yet been identified, though several possibilities are discussed below.

## III.C.2.1.4. OREGON: REINFORCEMENT OR REINTRODUCTIONS

Further information is needed before we can assess whether a need may exist for reinforcement or reintroduction of red foxes into Oregon, and the potential conservation benefits or risks of such translocations.

Qualitatively, SNRF appear to be more broadly distributed, and may be more abundant, in the Central Cascades study area than in other study areas. In the CLNP study area, however, SNRF numbers appear to be extremely low. Data from recent surveys suggest the population in this area is small or declining (S. Mohren, NPS, personal communication 2019).

### III.C.2.1.4.A. INFORMATION NEEDS

Continued monitoring and estimates of population size, density, and genetic diversity would provide a clearer picture of the status of SNRF populations throughout Oregon.

## III.C.2.1.5. MT. SHASTA: REINTRODUCTIONS

### III.C.2.1.5.A. POTENTIAL CONSERVATION BENEFITS

Grinnell et al. (1937) described the Mt. Shasta region as a population center of the SNRF, but recent surveys (summer surveys during 2009–2011 and winter surveys during 2015–2016; Figure 1) have not detected the subspecies in that region (CDFW and M. Immel, unpublished data). Reintroducing a population of red foxes to the Mt. Shasta region could create the opportunity for connectivity between Lassen, Shasta, and possibly even southern Oregon SNRF, potentially alleviating low genetic diversity and increasing population sizes over the long term. An additional independent population of SNRF would also increase the resilience to catastrophes of the subspecies as a whole.

### III.C.2.1.5.B. POTENTIAL RISKS

Geographic connectivity between Mt. Shasta and other extant SNRF populations is not assured, and a Mt. Shasta population could become isolated or extirpated. Presumed historical habitat in the Mt. Shasta region is located more than 100 linear km away from the nearest known SNRF populations. If managers are not highly confident in the potential for connectivity, reintroductions might require a large number of individuals to reduce the risk of inbreeding within a reintroduced population.

### III.C.2.1.5.C. INFORMATION NEEDS

Habitat analysis to assess the carrying capacities of and connectivity between the Lassen and Mt. Shasta regions would facilitate translocation planning. Analysis is needed to determine the ideal number of individuals and sex ratio for the reintroduction of a Mt. Shasta population, as well as whether successive translocations might be necessary over a period of years to sustain a reintroduced population.

An appropriate source population has not yet been identified, though several possibilities are discussed below.

### III.C.2.1.6. POTENTIAL SOURCE POPULATIONS

The IUCN recommends selecting sources for translocation stock based on genetic, morphological, physiological, and behavioral suitability, and prioritizing sources that are closer genetically and geographically to the recipient populations (IUCN 2013). Specifically, potential source populations for translocations to SNRF habitat should be evaluated according to the following criteria:

- **Similarity of reproductive timing:** To maximize the probability of reproductive success in translocated individuals, the timing of reproductive cycles in source animals should be similar to that experienced by SNRF (e.g., estrus in February–March). In addition to ensuring reproductive compatibility between source and recipient populations, similar reproductive timing may also be important to support neonatal survival in the mountain environment.
- **Morphological similarity:** SNRF have certain morphological characteristics that likely developed as adaptations to their environment, such as small body size, large foot size to mass ratio, thick winter coats, and small toe pads covered in dense hair in winter. Source animals without these characteristics may be less well adapted for survival in SNRF habitat.
- **Shared evolutionary history:** Source populations should be closely genetically related to SNRF. If populations of the SNRF subspecies are not available as sources, other subspecies from the montane subclade could be considered. Montane populations with minimal genetic admixture from non-montane sources would be preferable, though it is difficult to quantify a precise level of admixture at which a montane population would no longer be deemed appropriate for translocation into SNRF habitat.
- **Similarity of habitat:** Source populations that occupy montane, subalpine, and alpine habitat are likely to share behavioral and physiological adaptations that may translate to greater fitness in SNRF habitat. In the absence of information about reproductive timing, morphology, or genetic origins of potential source populations, similarity of habitat may enable a reasonable assumption of similarity in other parameters.
- **Ability to withstand removals:** Potential source populations must be able to withstand removal of animals without undue negative demographic or genetic consequences. Managers should establish thresholds for population estimates at which a given number of removals would not threaten the continued viability of a source population.

More detailed evaluation of potential source populations will be a necessary component of a translocation feasibility assessment. Here we provide a cursory review of these criteria as they pertain to red fox populations that have connectivity with SNRF populations or may be considered as future potential sources.

#### III.C.2.1.6.A. OREGON SNRF

SNRF in Oregon are the closest genetic relatives to SNRF in California, and may be their closest geographic relatives as well. Based on limited data from captures and observations, Oregon and California SNRF appear to have similar reproductive phenology and small body sizes. SNRF in Oregon can occur at lower elevations than SNRF in California, but typically occupy montane, subalpine, and alpine habitat. SNRF samples from the Central Cascades and CLNP study areas had minimal admixture according to recent genetic analyses (Quinn et al. in review), but samples from the Mt. Hood study area contained admixture from low-elevation populations of red foxes east of the Cascades, suggesting that SNRF from this study area may be less similar genetically to other SNRF.

Population estimates are not available for SNRF in Oregon. Anecdotal information suggests that the SNRF population in the CLNP study area is small or declining, but such a trend has not been detected in the Central Cascades study area. In order for managers to determine whether SNRF in any of the Oregon study areas would be a suitable source for translocations, reliable demographic data are needed to determine whether the population could withstand the removal of animals, as well as an analysis of the probability that translocated animals would survive in the release area and that recovery goals would be met. We currently do not have the data to provide this assurance.

### III.C.2.1.6.B. CASCADE RED FOXES

Cascade red foxes in Washington have genetic and phenotypic similarities to SNRF, with small body sizes, apparently similar reproductive phenology, and a montane genome with minimal admixture from non-montane sources (Akins et al. 2018). Cascade red foxes also inhabit similar montane and subalpine environments (Akins 2017). Cascade red fox populations may have higher genetic diversity than SNRF, but the genetic effective population size is estimated to be fewer than 20 individuals (Akins et al. 2018) and there is concern about a possible range reduction in northern Washington (J. Akins, Cascades Carnivore Project, personal communication 2019). Population estimates are needed to determine whether Cascade red fox populations could tolerate removals for translocation.

### III.C.2.1.6.C. ROCKY MOUNTAIN RED FOXES

Rocky Mountain red fox populations vary across their range in terms of degree of genetic introgression from non-montane populations (Quinn et al. in review). If Rocky Mountain red foxes were considered for translocations into SNRF habitat, individuals with smaller body sizes should be selected from high-elevation montane environments and from populations that have experienced little or no introgression from non-montane red foxes. Such foxes would be expected to have similar adaptations to those of the SNRF. For example, red foxes in the Colorado Rocky Mountains occur in similar subalpine and alpine habitats and may have a relatively pure montane genome, although additional data are needed to confirm this. Rocky Mountain red foxes in Colorado and other mountainous regions should be studied to detect populations where a high proportion of the montane genome remains intact and abundance is sufficient to allow removals.

### III.C.2.1.6.D. GREAT BASIN RED FOXES

Several admixed red foxes have immigrated into the SNRF population in the Sonora Pass study area and bred with SNRF females, potentially bringing about a natural genetic rescue[9]. Genetically, samples from the immigrants assigned most closely to a reference population in eastern Nevada, but it is possible that a closer population of Great Basin red foxes exists undetected in western Nevada or eastern California. Because we do not know the exact geographic origin of these immigrant red foxes, it is difficult to make assumptions about their habitat use, but red fox populations in the Great Basin inhabit both low- and high-elevation environments. The Great Basin red fox genome contains admixture from Rocky Mountain, eastern (e.g., fur farm), and potentially boreal red fox lineages (Quinn et al. in review). Individuals have larger body sizes than SNRF. The successful breeding between male Great Basin red foxes and female SNRF indicates a degree of compatibility. However, it is unknown when female red foxes from the Great Basin come into estrus. Low-elevation red foxes in California appear to experience estrus a month or more before SNRF females (Sacks et al. 2010b; C. Quinn, UC Davis, unpublished data; CDFW, unpublished data; ODFW, unpublished data). Such a mismatch in reproductive phenology, if present, could result in low reproductive success of Great Basin females translocated to the montane environment if pups were born before spring snowmelt and vegetation growth (e.g., Cross et al. 2018).

#### III.C.2.1.6.E. SACRAMENTO VALLEY RED FOXES

The Sacramento Valley red fox is phylogenetically related to the SNRF, but Sacramento Valley red foxes occupy lowland habitats and are phenotypically distinct from montane red foxes, with earlier estrus and larger bodies (Sacks et al. 2010b). The single documented immigrant into the Lassen SNRF population was a hybrid male primarily of eastern (e.g., fur farm) ancestry with a small component of Sacramento Valley red fox ancestry. While this immigrant successfully bred with SNRF females, we have no other evidence of connectivity between Sacramento Valley red foxes and SNRF.

#### III.C.2.1.6.F. OTHER RED FOX POPULATIONS IN OREGON

Different regions of Oregon are inhabited by multiple genetically differentiated populations of red foxes. In addition to SNRF in the Cascades, Rocky Mountain red foxes occur in the Wallowa and Blue Mountains[10], and admixed red foxes inhabit the lower elevations of the Columbia Basin and areas of central Oregon east of the Cascades. These latter low-elevation red foxes contain genetic admixture from multiple sources, including Rocky Mountain, eastern, and northern North American lineages (Quinn et al. in review). Genetic samples from SNRF in the Mt. Hood study area share a similar genetic composition with these admixed populations, but we do not know whether that reflects recent or historical connectivity.

Most samples of admixed red foxes in Oregon come from agricultural and developed areas lower in elevation than SNRF samples from the Oregon Cascades (Green et al. 2017; Quinn et al. in review). Anecdotally, red foxes in low-elevation central Oregon appear larger than SNRF (ODFW, unpublished data). As with other low-elevation red foxes, it is possible that Oregon red foxes occupying lower elevations come into estrus earlier than SNRF.

### III.C.2.1.7. RECIPROCAL TRANSLOCATIONS

Gene flow between 2 inbred but distinct populations can relieve the effects of inbreeding depression in subsequent generations of both populations (Edmands 2007; Fredrickson et al. 2007; Heber et al. 2012; Heber et al. 2013). Such reciprocal translocations have been proposed for ocelots in Texas (Janečka et al. 2014) and carried out successfully with Mexican wolves (Fredrickson et al. 2007). Genetic modeling could help to predict the magnitude and duration of genetic rescue resulting from reciprocal translocations between small, inbred populations of SNRF. Managers would need to weigh the risks of removing animals from these small populations, and of possible losses during capture or translocation, against the potential benefits of reciprocal translocations.

### III.C.2.1.8. CAPTIVE BREEDING

Rather than removing animals from a source population for immediate translocation, a captive breeding colony could be established for use in future translocations. The successful captive breeding programs for Scandinavian Arctic foxes (a montane species; Landa et al. 2017) and island foxes (Coonan et al. 2010) could serve as useful models. However, a similar program for SNRF may face a very different set of challenges. For example, SNRF exist at extremely low densities and high elevations, conditions that would be difficult to replicate in a captive breeding facility. The selection of founders for a captive breeding colony should consider the same criteria enumerated above for evaluation of potential source populations. At a minimum, a captive breeding effort would require substantial multi-year commitments of funding and personnel from wildlife management agencies and a zoo or other institutional partner.

## III.C.2.1.9. GENERAL CONSIDERATIONS

### III.C.2.1.9.A. REGULATORY CONSIDERATIONS

Any translocation effort would necessarily take place within the appropriate regulatory landscape. Analysis of potential environmental impacts would be required according to the National Environmental Policy Act (NEPA) for actions on federal lands and/or the California Environmental Quality Act (CEQA) for translocations in California. Permitting for capture, movement, and incidental take of animals may be required by CESA for translocations in California, and by ESA for actions affecting the Sierra Nevada DPS.

Reintroductions to unoccupied habitat on federal public lands, particularly in designated wilderness areas, would require the establishment of agreements between land and wildlife management agencies specific to reintroduction efforts. For this reason, regulatory approval for reintroductions may require a longer timeframe than approval for reinforcement translocations in habitat that is already occupied.

### III.C.2.1.9.B. TRANSLOCATION SPECIFICS

In addition to determining the appropriate number and sex ratio of translocated individuals, a translocation feasibility assessment should consider optimal age classes and timing of capture and release. In an island fox population, both wild-caught and captive-bred juveniles were translocated within Santa Catalina Island with high survival rates (90% and 100% respectively 1 year post-release for juveniles released in 2001, compared to 60% in the same year for wild juveniles that were not translocated; King et al. 2014). A translocation effort for swift foxes in Canada found that survival rates were similar between translocated juveniles and adults, and litter sizes of translocated juveniles were comparable to those of resident adults (Moehrenschlager and Macdonald 2006). Juvenile foxes would need to be independent (5–6 months old) prior to translocation.

It is possible that translocation of juveniles could functionally mimic natural dispersal at the population level, such that removing juveniles could entail lower impacts to source populations than removing adults. However, a population viability analysis produced by Kohlmann et al. (2005) found increased extinction risk for an island fox population from which juveniles were removed for translocations, and in practice translocation removals ceased after 2 years when the source population dropped below a predetermined abundance threshold (King et al. 2014). While removing juveniles may have less effect on source populations than removing adults, we reiterate that removal of any individuals may be problematic for very small populations.

Reintroductions to establish new populations in unoccupied habitat would likely require more individuals than reinforcement translocations. Given the small size and number of potential source populations, only a small number of animals may be available for translocation. A translocation feasibility assessment should consider the highest priority uses for this limited stock.

Using current best estimates of SNRF survival and recruitment (e.g., Quinn et al. 2019), a translocation feasibility assessment could model the impacts of various removal, reinforcement, and reintroduction scenarios on source and recipient populations of different sizes. Translocations of other fox species and genera (e.g., island foxes in California's Channel Islands; swift foxes in Alberta,

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[9] See II.D.2. Current Population Status: Sierra Nevada.

Saskatchewan, Montana, and South Dakota; Arctic foxes in Norway) may provide useful insight into best practices to guide SNRF translocations.

#### III.C.2.1.9.C. MONITORING

Explicit goals for a translocation must be established, and the success or failure of translocation efforts must be assessed through monitoring (IUCN 2013). Translocation planning should consider the relative ease of monitoring in each proposed location and confirm that effective monitoring protocols are in place and have sufficient power to detect trends.

If carefully implemented and successful, translocations would contribute to meeting Goal 2 ("Ensure that viable populations of SNRF persist within the historical range") of this Strategy by fulfilling Objective 2.a ("Ensure that extant populations of SNRF are viable, genetically diverse, and resilient to chance deleterious events and environmental change") and Objective 2.b ("Maintain or increase the distribution of SNRF within the historical range to enhance connectivity and resilience").

## III.C.3. TIER 3

*Management actions that are not currently warranted but may be considered if future evidence indicates a need.*

### III.C.3.1. VACCINATION

We have no evidence of mortality due to disease in any SNRF population, but systematic surveillance has not occurred and diseases may be present but undetected. Diseases like mange, canine distemper, canine parvovirus, and rabies have the potential to rapidly exterminate small populations. Vaccines are available for canine distemper, canine parvovirus, and rabies, but typically need to be repeated periodically to be effective. Vaccination efforts have been successful in recovering other species faced with high extinction risk due to disease: notably, black-footed ferrets (vaccinated for distemper and plague, Salkeld 2017), Ethiopian wolves (vaccinated for rabies, Randall et al. 2004), and island foxes (vaccinated for distemper, Coonan et al. 2010). Mange-infected foxes can be treated, but may be reinfected within months if they are in contact with untreated, infected foxes.

In order to detect diseases in SNRF populations, researchers and veterinarians should collect cause of mortality data and biological samples from necropsied SNRF, conduct examinations of and collect biological samples from live-captured SNRF, and analyze SNRF scat samples to determine the presence of pathogens or parasites of high conservation threat (e.g., canine distemper, canine parvovirus, mange). If feasible, it may be useful to collect cause of mortality data and biological samples from necropsied sympatric carnivores to detect pathogens or parasites that could be transmitted to SNRF.

If potentially treatable or preventable diseases are detected in SNRF or sympatric carnivores, consultation with CDFW and/or ODFW veterinarians is immediately warranted. A decision to treat or vaccinate will likely depend on the degree of morbidity or mortality observed, the potential for an outbreak, and the safety and feasibility of administering the treatment or vaccine. Advisement on currently available vaccines safe for red foxes, or novel treatments in use, may be sought from other agencies and zoological institutions. Efforts to treat or administer vaccines to SNRF would be challenged by availability of funding, the practical difficulties of capturing SNRF, and the likely need for booster vaccinations and retreatments to ensure protection.

If a disease threat was determined to be severe, a trapping effort specifically targeted to capture and vaccinate or treat SNRF might be warranted immediately, despite the inherent difficulties of such captures. Subsequent to this initial response, a long-term vaccination strategy could rely on opportunistic vaccination/treatment of SNRF during captures, vaccination/treatment targeting specific populations or geographic areas, or, potentially, vaccination/treatment of sympatric species.

If a disease threat were documented in SNRF, these measures would contribute to meeting Goal 3 (“Mitigate individual- and population-level threats to SNRF”) of this Strategy. No action is currently warranted.

### III.C.3.2. RECREATION REGULATIONS

Very limited evidence is available of negative impacts to SNRF due to specific recreation activities. As detailed in section III.B.2.5. Recreation Effects, further research is needed to investigate potential threats to SNRF from recreation. If studies found significant negative population-level impacts of recreation on SNRF, managers could consider regulating use (e.g., requiring dogs to be on leash in SNRF habitat; enforcing quotas or boundaries for OSV or OHV use, hiking, or camping). Such measures may be unpopular or difficult to implement, and should only be considered if sufficient evidence indicates they are necessary to protect SNRF. Instead of or in addition to restricting recreation activities, managers could also promote better practices through public education, as outlined in III.C.1.3. Management Actions: Tier 1: Recreation Management.

If a recreation threat to SNRF was documented, regulating use could contribute to meeting Goal 3 (“Mitigate individual- and population-level threats to SNRF”) of this Strategy. No action is currently warranted.

### III.C.3.3. HUNTING AND TRAPPING REGULATIONS

According to ODFW, changes to hunting and trapping regulations are not warranted based on harvest records of red foxes in Oregon and communication with licensed furtakers suggesting that limited trapping activity occurs within SNRF habitat. Prohibiting SNRF harvest would be very difficult to regulate and enforce given that multiple red fox subspecies occur in counties where harvest takes place, and harvested foxes are not identified by subspecies. ODFW continues to monitor red fox harvest levels but does not expect any increase in harvested red foxes or injuries to red fox by-catch in the future.

## III.C.4. OTHER ACTIONS

*Management actions that are not currently warranted and may not be feasible even if future evidence indicates a need.*

### III.C.4.1. COYOTE CONTROL

While antagonistic interactions between coyotes and red foxes are well documented in other regions, these interactions have not been studied thoroughly in SNRF habitat, and we have no evidence that coyote predation or competition are significant threats to the SNRF. The literature suggests that attempts to control coyote populations at large spatial scales are typically unsuccessful (Connolly and Longhurst 1975; USFWS 1978). Furthermore, implementing control actions may not be feasible in many areas where SNRF occur, such as wilderness areas and National Parks. Collaring coyotes could enable the study of competitive dynamics and detection of individuals that predate on SNRF, but removal of individual coyotes would not likely achieve population-level control. Coyote control is currently neither warranted nor feasible in SNRF habitat.

It is reasonable, however, to assume that SNRF would benefit from lower densities of sympatric coyotes. Education and trash disposal geared toward reducing the incidence of coyote habituation in SNRF habitat may contribute to protecting SNRF from negative interactions with coyotes. Development, recreation, or road-building should be discouraged if these activities lead to habituation of coyotes in SNRF habitat or create corridors facilitating coyote movement into SNRF habitat. Further study of coyote-SNRF dynamics would enhance our understanding of the level of threat coyotes pose to SNRF conservation.

### III.C.4.2. PREY ENHANCEMENT

The low productivity of alpine and subalpine environments may limit prey populations, reducing available food for SNRF and creating more potential for competition with other carnivores. Climate change and land management activities may also affect prey populations by altering their habitat. Our understanding of SNRF prey preference and availability is inadequate to justify these conditions as threats, and we do not recommend that managers augment prey populations through translocations. Increasing prey density would also carry the potential risk of a disproportionate benefit to SNRF competitors. Land management prescriptions intended to conserve or enhance habitat for SNRF prey, as described above in section III.C.1.4. Management Actions: Tier 1: Land Management are likely a more reliable means of maintaining adequate prey populations.

# III.D. PLANNING AND COLLABORATION

This Strategy represents an initial framework for SNRF conservation, highlighting in particular the information gaps that preclude more specific management recommendations. Here we identify the planning and coordination tasks that are critical to the next phase of species recovery.

## III.D.1. COORDINATION AMONG AGENCIES AND RESEARCHERS

Multiple agencies and individuals conduct SNRF research and manage SNRF populations and habitat. Continued coordination between these entities will be crucial to meeting the information needs outlined in this Strategy and supporting ongoing conservation planning for the SNRF.

Each agency or researcher manages and stores data according to an internal system. Range-wide data analyses entail independent coordination with each agency, and differing methods may hinder comparisons between data sets. The nature of the study area or research objectives often dictates the methods used, but at a broad scale, studies with similar objectives would benefit from a shared protocol such as the monitoring guidelines outlined in Appendix B. Once data are collected, storage in a central location according to a unified procedure would facilitate analyses, updates to the Strategy, and other conservation planning efforts. Finally, a process by which the SNRF Working Group or SCAT could collaboratively evaluate proposals would streamline external requests to analyze SNRF data.

## III.D.2. TRANSLOCATION FEASIBILITY ASSESSMENT

The small size, low genetic diversity, inbreeding, and isolation of at least 2 of the 3 extant SNRF populations (Lassen and Sierra Nevada) points to genetic and/or demographic rescue as a potentially urgent conservation need. Translocations may be an effective tool to meet this need, but a thorough analysis is needed to determine whether and how movement of animals can be carried out safely, feasibly, and effectively. A formal translocation feasibility assessment, conducted according to the

IUCN's *Guidelines for Reintroductions and Other Conservation Translocations* (IUCN 2013), would allow managers to weigh the costs and benefits of implementing such a program. A translocation feasibility assessment would identify possible source populations, prioritize recipient populations and release locations, and develop quantitative goals for SNRF translocations, as well as evaluating the feasibility of a captive breeding program and exploring the logistical constraints and information gaps that may hinder progress. This assessment will likely require a dedicated team and funding over the next 1 to 2 years.

Further research and analysis are needed to inform discussions about source and recipient populations. Wherever reinforcement or reintroduction are under consideration, particularly in the Lassen Peak region, available habitat and possible release sites must be identified. Criteria must be developed to establish whether a population can safely provide animals for translocation. For populations that may have the potential to serve as sources, current population estimates are needed along with modeled responses to various removal scenarios.

If an appropriate source population cannot be identified, a feasibility assessment for captive breeding may be the next step in evaluating options for species recovery.

## III.D.3. RANGE-WIDE GENETIC MANAGEMENT PLAN

Each SNRF population is subject to distinct genetic influences. Genetic diversity and the potential for inbreeding or outbreeding depression also vary between populations. In addition to the Genetic Management Plan that is in preparation, there is a need to expand on and update range-wide analyses to explore the potential genetic consequences of different translocation or immigration scenarios, including reciprocal translocations, as well as the likely genetic future of each population if translocations do not occur.

## III.D.4. STRATEGY REVISION

As we learn more about the SNRF, the Strategy must change to reflect our changing understanding. New information frequently comes to light when research updates are presented each year at the SNRF Working Group meeting. Notes from this meeting should be appended annually to the Strategy website. In conjunction with or subsequent to the SNRF Working Group meeting, or at an interim meeting called to discuss significant findings, the SCAT should consider whether amendments or revisions to the Strategy are warranted. If so, a team should be tasked with implementing these changes and distributing them to stakeholders. The Strategy website will house the most up-to-date versions of all Strategy components, and readers should be directed to this website rather than to a physical document to ensure they access the most current information.

## III.D.5. RANGE-WIDE REGULATORY SUPPORT

Conservation planning for the SNRF will be most effective if it occurs at the scale of the subspecies' entire range, taking into account all extant populations as well as areas of the historical range not known to be occupied currently. Interagency support from researchers, managers, and planners throughout the range will be critical to ensuring a cohesive and comprehensive strategy to realize the conservation vision for the SNRF.

USFWS's Distinct Vertebrate Population Segment policy is based on 3 criteria: discreteness of a population segment from other populations of the species, significance of a population segment to the continued viability of the species, and status (or degree to which a population segment is threatened or endangered; USFWS and National Marine Fisheries Service 1996).

The most current information about SNRF distribution and genetic structure indicates that there is no evidence of recent connectivity between the Oregon, Lassen, and Sierra Nevada populations of the SNRF (Quinn et al. in review). Additionally, these populations are geographically segregated, with at least 270 linear km between each population and its nearest neighbor. Because these are the only locations where SNRF are known to exist, it could be argued that the extirpation of any of these populations would produce a disjunct range. While we do not have the information to determine the status of the Oregon population, the Lassen population is likely vulnerable to extirpation due to very small population size, low genetic diversity, and inbreeding.

The Oregon and Lassen populations were combined into a single DPS in USFWS's 12- month finding (USFWS 2015a). Recovery planning for the federally endangered Sierra Nevada DPS would benefit by taking into consideration the most up-to-date understanding of connectivity and differentiation of SNRF populations, and seeking to address the range-wide conservation needs of the SNRF.

# IV. RECOMMENDATIONS AND IMPLEMENTATION

The next steps in SNRF conservation fall into 3 categories: addressing Tier 1 and Tier 2 information needs, implementing Tier 1 management actions, and continuing collaborative planning efforts. We outline a simple decision framework (Figure 55) to aid researchers and managers in focusing their work on the recommendations that apply to them most directly. Recommendations are also summarized in tabular format (Table 2) to facilitate tracking progress. More information about the current status, implementation challenges, and estimated resource needs of each recommended action are provided in Appendix A. These recommendations are subject to periodic revision as actions are completed or new priorities emerge.

## IV.A. INFORMATION NEEDS RECOMMENDATIONS

**IV.A.1. Range-wide**: Continue to monitor abundance, distribution, health, and genetic composition of known populations.

- **IV.A.1.1. Lassen**: Continue to monitor SNRF abundance and distribution in the Lassen Peak and Caribou Wilderness areas.
- **IV.A.1.2. Lassen**: Monitor genetic diversity and genetic effective population size and attempt to detect immigration events.
- **IV.A.1.3. Sierra Nevada**: Continue to monitor SNRF abundance and distribution in the Sonora Pass, YNP, and Mono Creek study areas.
- **IV.A.1.4. Sierra Nevada**: Monitor genetic diversity and genetic effective population size and attempt to detect immigration and dispersal events. Track rate and prevalence of genetic admixture.
- **IV.A.1.5. Oregon**: Continue to monitor SNRF abundance and distribution. Ensure monitoring methods can be used to generate population estimates.
- **IV.A.1.6. Oregon**: Monitor genetic diversity and connectivity between SNRF study areas and between SNRF and Rocky Mountain or

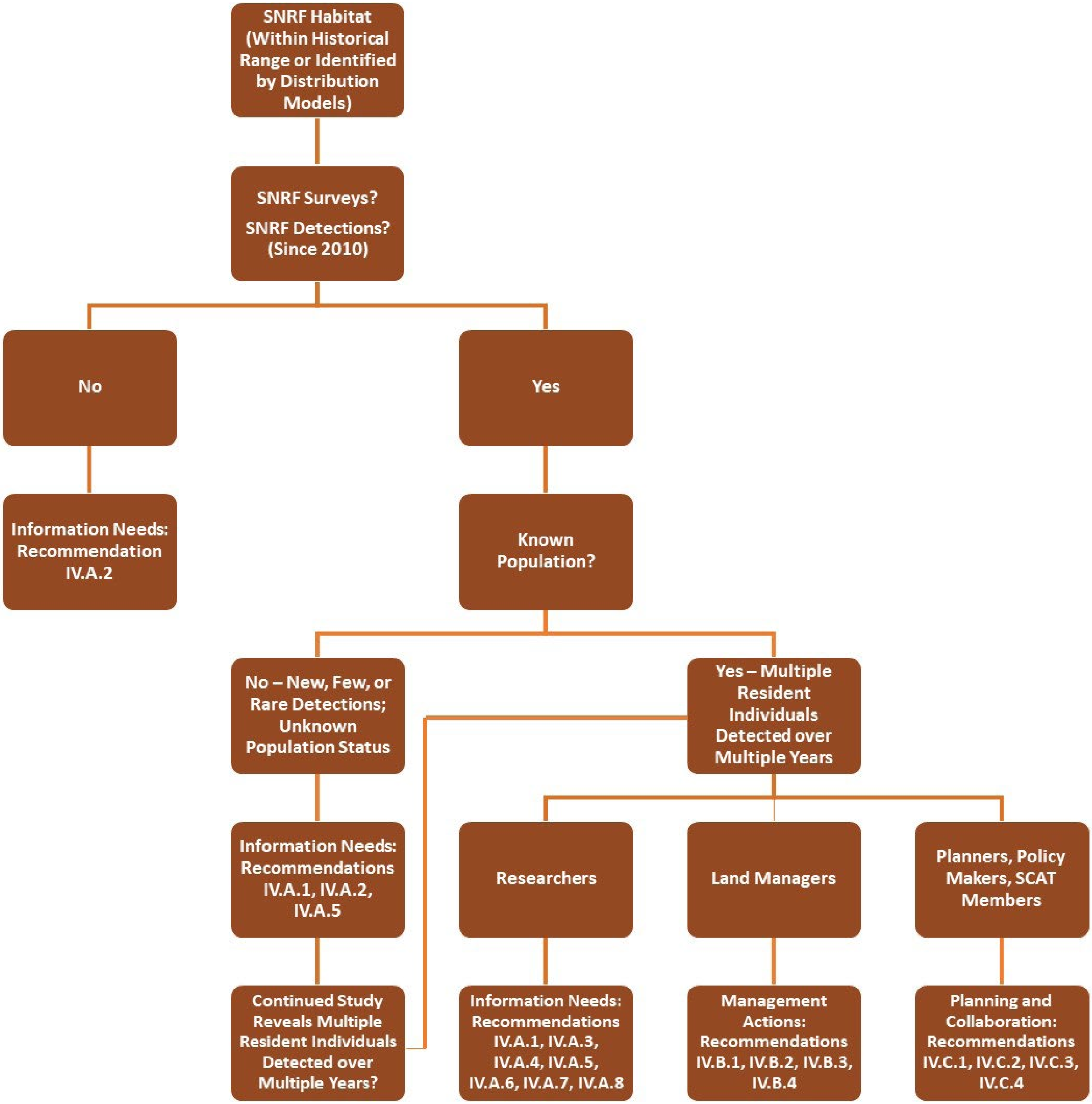

Figure 55. Recommendations decision tree.

admixed red fox populations. Monitor possible contact zones between SNRF and other red fox populations.

**IV.A.1.7. Oregon**: Determine the number of SNRF harvested annually and the proportion this harvest represents of the total SNRF population in Oregon.

**IV.A.2. Range-wide**: Conduct systematic, coordinated, extensive surveys for SNRF, following the Survey and Monitoring Guidelines in this document, in areas of suitable habitat that have not been surveyed or where SNRF have not been detected.

**IV.A.2.1. Sierra Nevada**: Survey high elevations (above 2,500 m) of Sequoia and Kings Canyon National Parks and areas of high habitat suitability east of the park boundaries.

**IV.A.2.2. Oregon**: Identify and survey apparent gaps in distribution, including south of CLNP, between CLNP and the Central Cascades study area, and between the Central Cascades study area and Mt. Hood.

**IV.A.3. Range-wide**: Improve understanding of SNRF vital rates, health, and resource utilization.

**IV.A.3.1. Range-wide**: Assess and track SNRF individuals through captures and deployment of GPS collars.

**IV.A.3.2. Range-wide**: Collect biological samples (tissue and/or blood) from all captured or necropsied SNRF for genetic and disease analysis. Conduct histology, PCR, serology, and toxicology testing. Perform physical exams to assess body condition of all captured SNRF. Perform full necropsies on all SNRF mortalities whenever carcass condition is suitable.

**IV.A.3.3. Range-wide**: Investigate home-range size, fine-scale habitat selection, seasonal habitat use, and den-site selection.

**IV.A.3.4. Range-wide**: Determine reproductive rates, timing of reproduction, litter size, and juvenile recruitment rates.

**IV.A.3.5. Range-wide**: Investigate mortalities to determine cause of death and estimate survival rates.

**IV.A.4. Range-wide**: Assess the risk of outbreeding depression in admixed SNRF populations by identifying local adaptations of the SNRF genome.

**IV.A.5. Range-wide**: Refine SNRF distribution and habitat models.

**IV.A.5.1. Range-wide**: Assess accuracy of models by ground-truthing with survey data.

**IV.A.5.2. Range-wide**: Investigate the influence of land management activities (e.g., timber harvest, prescribed fire, grazing) on SNRF presence or habitat selection. Determine fine-scale characteristics that affect habitat suitability for SNRF and identify land management activities that could alter or preserve these characteristics.

**IV.A.5.3. Range-wide**: Investigate the influence of human recreation and development on SNRF presence or habitat selection.

**IV.A.5.4. Range-wide**: Evaluate existing habitat connectivity for SNRF and assess the potential for habitat fragmentation. Identify barriers to connectivity or colonization.

**IV.A.5.5. Range-wide**: Determine what factors influence denning success and at what distance from den sites. Use this information to estimate reasonable buffers to protect SNRF den sites from disturbance or loss of critical habitat characteristics

**IV.A.6. Range-wide**: Study sympatric carnivores (coyotes, gray foxes, martens, bobcats, mountain lions) and their distribution, abundance, habitat use, and interactions with SNRF.

**IV.A.6.1. Range-wide**: Estimate density, abundance, and distribution of sympatric carnivores. Identify seasonal and long-term changes in these parameters (e.g., elevational shift in species distribution with climate change; density of other carnivores in SNRF habitat in winter vs. summer).

**IV.A.6.2. Range-wide**: Identify diet niche width and overlap for SNRF and sympatric carnivores, particularly in winter.
**IV.A.6.3. Range-wide**: Determine whether sympatric carnivores limit SNRF distribution. Assess variation in activity patterns (e.g., temporal or spatial partitioning) or occupancy of SNRF in the presence of other carnivores.
**IV.A.6.4. Range-wide**: Identify direct (e.g., predation) and indirect (e.g., competition for prey or habitat, disease transmission) impacts of sympatric carnivores on SNRF fitness.
**IV.A.6.5. Range-wide**: Test sympatric carnivores for infection and exposure to diseases of conservation concern through necropsy of fresh mortalities or by-catch of live animals.

**IV.A.7. Range-wide**: Document effects of recreation on SNRF behavior, habitat use, survival, and reproductive success.
**IV.A.7.1. Range-wide**: Implement recreation intensity studies to compare recreation use data (e.g., GPS tracks from recreationists) to location data from collared SNRF. Identify areas and timing of overlap and determine whether patterns of space use in SNRF appear to be influenced by type, timing, or intensity of recreation use.
**IV.A.7.2. Range-wide**: Locate SNRF dens and assess their proximity to recreation activities.
**IV.A.7.3. Range-wide**: Assess the level of habituation in each SNRF population or study area. Record instances of apparent habituation and estimate the number of habituated individuals.
**IV.A.7.4. Range-wide**: Identify sources and amounts of anthropogenic food or trash available to SNRF and determine the main vectors for habituation (e.g., parking lots, campgrounds, resorts, backcountry use areas). In areas where habituation has been documented, assess the efficacy of current methods for collecting, storing, and removing anthropogenic food or trash.
**IV.A.7.5. Range-wide**: Document interactions between domestic dogs and SNRF or other wildlife.
**IV.A.7.6. Range-wide**: Evaluate success of methods used to deter or relocate habituated SNRF or similar species.

**IV.A.8. Range-wide**: Determine sources and availability of SNRF food, particularly during winter and spring, including reliance on anthropogenic food or trash.
**IV.A.8.1.** Perform diet analysis (e.g., metagenomic or stable isotope analysis) of scat and hair samples collected during ongoing monitoring.
**IV.A.8.2.** Determine reliance of SNRF on leporid prey, particularly in winter. Estimate occupancy and abundance of leporids in SNRF habitat and identify any impacts of RHDV-2.
**IV.A.8.3.** Determine SNRF use of or reliance on carrion killed by other carnivores.
**IV.A.8.4.** Document the prevalence of anthropogenic food or trash in the diet of habituated SNRF and identify possible sources.

## IV.B. MANAGEMENT ACTIONS RECOMMENDATIONS

**IV.B.1. Range-wide, Oregon**: Identify places where SNRF cross roads, especially places associated with vehicle strikes. At known SNRF crossings, implement any feasible management actions to protect SNRF from vehicle strikes, especially near den sites.

**IV.B.2. Range-wide**: Continue to evaluate current land use and management prescriptions and develop best land management practices to protect SNRF habitat[11].
**IV.B.2.1. Range-wide**: Consider the potential

impacts to SNRF when permitting new recreation uses or development in SNRF habitat. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3. Rodenticides, and III.A.7. Recreation, Habituation, and Development. If feasible, minimize new recreational uses or developments, such as roads, trails, parking lots, campgrounds, resorts, and OHV or OSV areas, that would result in substantially increased human or motor vehicle presence in areas used by SNRF.

**IV.B.2.2. Range-wide**: Consider the potential impacts to SNRF when planning or permitting land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3. Rodenticides, III.A.8. Food Availability, and III.A.12. Land Use and Management. If feasible, minimize land uses or developments that would result in substantially increased human or motor vehicle presence in SNRF habitat.

**IV.B.2.3. Range-wide**: Consider the potential impacts to small mammal prey species, particularly leporids, when planning or permitting land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in section III.A.12. Land Use and Management, and include loss of habitat due to removal of forest understory structure or to tree and shrub encroachment in meadow habitats.

**IV.B.2.4. Range-wide**: Maintain or enhance meadows in SNRF habitat within their natural range of variation, restoring or preserving hydrologic function and plant species composition.

**IV.B.2.5. Range-wide**: To the extent consistent with fuels reduction, vegetation treatment, and thinning activities necessary for forest health and fire risk reduction, maintain elements of understory structure in forested SNRF habitat to provide cover for forest-floor-dwelling small mammal species.

**IV.B.2.6. Range-wide**: Maintain subalpine and montane forests in SNRF habitat within their natural range of variation to support the health of mast species such as whitebark pine.

**IV.B.2.7. Range-wide**: When a den site is identified, coordinate with wildlife managers to determine appropriate land use, management, or recreation activities in that vicinity. Because data on active den sites are too limited currently to inform estimates of the area that constitutes the vicinity of a den, land and wildlife managers should work together to determine an appropriate buffer, keeping in mind that SNRF may use more than 1 den site during the period of pup dependency and may travel relatively long distances away from den sites.

**IV.B.2.8. Range-wide**: When issuing special use permits for events in SNRF habitat, consider the location, size, and timing of events relative to known SNRF den sites and the period of increased vulnerability during denning season (at minimum, late pregnancy through the pre-weaning period, roughly April 1–August 1), as well as whether events will likely introduce anthropogenic food or trash into SNRF habitat.

**IV.B.3. Range-wide**: Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation.

**IV.B.3.1. Range-wide**: Encourage pet owners to prevent pet aggression toward SNRF and

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[11] For the purposes of these and other recommendations pertaining to land management, "SNRF habitat" is defined as areas known to be occupied by SNRF (i.e., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the historical range (e.g., Green et al. in preparation; Stermer in preparation). These recommendations are intended to apply only within SNRF habitat.

minimize potential disease transmission by leashing pets, removing pet waste, and ensuring pets are vaccinated for common diseases such as rabies and canine distemper.

**IV.B.3.2. Range-wide**: Discourage use of rodenticides at resorts and residences in occupied SNRF habitat.

**IV.B.3.3. Range-wide**: Continue to provide and improve general educational materials about SNRF for the public and the media.

IV.B.3.4. Range-wide: Continue to engage the public in citizen science efforts to monitor SNRF, including by encouraging reporting of observations to appropriate managers and submission of photos if available to confirm identification.

**IV.B.3.5. Range-wide**: Protect sensitive location data, especially den site locations, from public knowledge.

**IV.B.4. Range-wide**: Reduce incidence of SNRF habituation due to availability of anthropogenic food or trash in SNRF habitat.

**IV.B.4.1. Range-wide**: Discourage feeding SNRF or making trash available to scavenging SNRF or other sympatric carnivores such as bears, coyotes, or gray foxes.

**IV.B.4.2. Range-wide**: Provide carnivore-proof trash receptacles at developed recreation sites within SNRF habitat, particularly in winter and in locations where trash can accumulate, such as parking lots and campgrounds.

# IV.C. PLANNING AND COLLABORATION RECOMMENDATIONS

**IV.C.1. Range-wide**: Complete a translocation feasibility assessment.

**IV.C.1.1. Range-wide**: Continue genetic research to inform a range-wide genetic management plan.

**IV.C.1.2. Range-wide**: Assess the feasibility of a captive breeding program.

**IV.C.1.3. Lassen**: Assess the carrying capacity of the Lassen Peak region and identify possible release sites to facilitate translocation planning.

**IV.C.1.4. Oregon**: Evaluate the potential for SNRF in Oregon to serve as source stock for future translocations.

**IV.C.1.5. Other States**: Evaluate the potential for non-SNRF montane red fox populations (such as Cascades red foxes in Washington and Rocky Mountain red foxes in Colorado) to serve as source stock for future translocations.

**IV.C.2. Range-wide**: Create better systems to manage, store, and share SNRF data across regions and agencies.

**IV.C.3. Range-wide**: Ensure new information about the SNRF is integrated periodically into revisions or amendments to the Strategy.

**IV.C.4. Range-wide**: Improve regulatory support for range-wide SNRF conservation.

Table 2. Strategy recommendations and current implementation status.

| **IV.A. Information Needs Recommendations** | | |
|---|---|---|
| **Region** | **Recommendation** | **Status** |
| Range-wide | IV.A.1. Continue to monitor abundance, distribution, health, and genetic composition of known populations. | Ongoing |
| Range-wide | IV.A.2. Conduct systematic, coordinated, extensive surveys for SNRF, following the Survey and Monitoring Guidelines in this document, in areas of suitable habitat that have not been surveyed or where SNRF have not been detected. | Ongoing |
| Range-wide | IV.A.3. Improve understanding of SNRF vital rates, health, and resource utilization. | Ongoing in Lassen population. Ongoing in Central Cascades study area. Planned in Sonora Pass study area. |
| Range-wide | IV.A.3.1. Assess and track SNRF individuals through captures and deployment of GPS collars. | Ongoing in Lassen population. Ongoing in Central Cascades study area. Planned in Sonora Pass study area. |
| Range-wide | IV.A.3.2. Collect biological samples (tissue and/or blood) from all captured or necropsied SNRF for genetic and disease analysis. Conduct histology, PCR, serology, and toxicology testing. Perform physical exams to assess body condition of all captured SNRF. Perform full necropsies on all SNRF mortalities whenever carcass condition is suitable. | Ongoing in Lassen population. Tissue but not blood samples are taken from captured SNRF in Central Cascades study area. |
| Range-wide | IV.A.3.3. Investigate home range size, fine-scale habitat selection, seasonal habitat use, and den-site selection. | Ongoing in Lassen population. Ongoing in Central Cascades study area. Planned in Sonora Pass study area. |
| Range-wide | IV.A.3.4. Determine reproductive rates, timing of reproduction, litter size, and juvenile recruitment rates. | Some reproductive data have been gathered in the Lassen, Central Cascades, and Sonora Pass study areas. Overall vital rates have not been established. |
| Range-wide | IV.A.3.5. Investigate mortalities to determine cause of death and estimate survival rates. | Mortalities of collared animals are investigated in the Lassen and Central Cascades study areas. Survival rates have been estimated in the Sonora Pass study area using scat samples. |
| Range-wide | IV.A.4. Assess the risk of outbreeding depression in admixed SNRF populations by identifying local adaptations of the SNRF genome. | Ongoing in Sierra Nevada population. |
| Range-wide | IV.A.5. Refine SNRF distribution and habitat models. | Ongoing |

| | | |
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| Range-wide | IV.A.5.1. Assess accuracy of models by ground-truthing with survey data. | Not started |
| Range-wide | IV.A.5.2. Investigate the influence of land management activities (e.g., timber harvest, prescribed fire, grazing) on SNRF presence or habitat selection. Determine fine-scale characteristics that affect habitat suitability for SNRF and identify land management activities that could alter or preserve these characteristics. | Not started |
| Range-wide | IV.A.5.3. Investigate the influence of human recreation and development on SNRF presence or habitat selection. | Not started |
| Range-wide | IV.A.5.4. Evaluate existing habitat connectivity for SNRF and assess the potential for habitat fragmentation. Identify barriers to connectivity or colonization. | Not started |
| Range-wide | IV.A.5.5. Determine what factors influence denning success and at what distance from den sites. Use this information to estimate reasonable buffers to protect SNRF den sites from disturbance or loss of critical habitat characteristics. | Not started |
| Range-wide | IV.A.6. Study sympatric carnivores (coyotes, gray foxes, martens, bobcats, mountain lions) and their distribution, abundance, habitat use, and interactions with SNRF. | Remote cameras deployed for SNRF surveys also collect distribution data for sympatric carnivores; however their abundance, habitat use, and interactions with SNRF have not been studied. |
| Range-wide | IV.A.6.1. Estimate density, abundance, and distribution of sympatric carnivores. Identify seasonal and long-term changes in these parameters (e.g., elevational shift in species distribution with climate change; density of other carnivores in SNRF habitat in winter vs. summer). | Coyote density in winter and summer was estimated in the Sonora Pass study area (Quinn 2018). |
| Range-wide | IV.A.6.2. Identify diet niche width and overlap for SNRF and sympatric carnivores, particularly in winter. | Poisson et al. (2019) investigated diet niche width and overlap for SNRF and coyotes in Oregon. |
| Range-wide | IV.A.6.3. Determine whether sympatric carnivores limit SNRF distribution. Assess variation in activity patterns (e.g., temporal or spatial partitioning) or occupancy of SNRF in the presence of other carnivores. | Not started |
| Range-wide | IV.A.6.4. Identify direct (e.g., predation) and indirect (e.g., competition for prey or habitat, disease transmission) impacts of sympatric carnivores on SNRF fitness. | Not started |

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| Range-wide | IV.A.6.5. Test sympatric carnivores for infection and exposure to diseases of conservation concern through necropsy of fresh mortalities or by-catch of live animals. | Not started |
| Range-wide | IV.A.7. Study effects of recreation on SNRF behavior, habitat use, survival, and reproductive success. | Not started |
| Range-wide | IV.A.7.1. Implement recreation intensity studies to compare recreation use data (e.g., GPS tracks from recreationists) to location data from collared SNRF. Identify areas and timing of overlap and determine whether patterns of space use in SNRF appear to be influenced by type or concentration of recreation use. | Not started |
| Range-wide | IV.A.7.2. Locate SNRF dens and assess their proximity to recreation activities. | SNRF dens have been located in the Lassen and Central Cascades study areas using GPS collar location data from denning females. |
| Range-wide | IV.A.7.3. Assess the level of habituation in each SNRF population or study area. Record instances of apparent habituation and estimate the number of habituated individuals. | Habituation has been documented anecdotally, but not systematically, in each population. |
| Range-wide | IV.A.7.4. Identify sources and amounts of trash or human food available to SNRF and determine the main vectors for habituation (e.g., parking lots, campgrounds, resorts, backcountry use areas). In areas where habituation has been documented, assess the efficacy of current methods for collecting, storing, and removing trash and human food. | Some sources of trash and food have been identified, but a comprehensive survey of vectors for habituation has not taken place. |
| Range-wide | IV.A.7.5. Document interactions between domestic dogs and SNRF or other wildlife. | A SNRF was killed by a domestic dog in the Lassen study area in 2002. Although domestic dogs are known to be present in multiple areas occupied by SNRF, no other interactions have been documented to date. |
| Range-wide | IV.A.7.6. Evaluate success of methods used to deter or relocate habituated SNRF or similar species. | Not started |
| Range-wide | IV.A.8. Determine sources and availability of SNRF food, particularly during winter and spring, including reliance on human food. | SNRF diet studies have been completed in Lassen and Oregon. Studies of prey availability have not been conducted. |
| Range-wide | IV.A.8.1. Perform diet analysis (e.g., metagenomic or stable isotope analysis) of scat and hair samples collected during ongoing monitoring. | SNRF diet studies have been completed in Lassen and Oregon. |

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| Range-wide | IV.A.8.2. Determine reliance of SNRF on leporid prey, particularly in winter. Estimate occupancy and abundance of leporids in SNRF habitat and identify any impacts of RHDV-2. | Leporid remains were virtually absent from SNRF scats collected in the Lassen study area during 1998-2002 (Perrine 2005), but were found in 15% of scats collected in the same area during 2008-2015, and were more frequent (44%) in scats collected during winter and spring (CDFW and UC Davis, unpublished data). Snowshoe hare was a dominant component in SNRF scats collected in Oregon during 2017-2018 (Poisson et al. 2019). Occupancy and abundance of leporids in SNRF habitat have not been formally investigated. The incidence of RHDV-2 in California is being monitored closely. |
| Range-wide | IV.A.8.3. Determine SNRF use of or reliance on carrion killed by other carnivores. | Mule deer (presumably as carrion) was a major component of SNRF diet in winter during Perrine's (2005) study in the Lassen population. Later studies in Lassen (CDFW and UC Davis, unpublished data) and Oregon (Poisson et al. 2019) also detected large ungulate prey in SNRF scats. |
| Range-wide | IV.A.8.4. Document the prevalence of anthropogenic food in the diet of habituated SNRF and identify possible sources. | Although SNRF have been observed begging for and eating anthropogenic food, the prevalence of such items in the SNRF diet has not been quantified and not all possible sources have been identified. |
| | | |
| Oregon | IV.A.1.5. Continue to monitor SNRF abundance and distribution. | Ongoing |
| Oregon | IV.A.1.6. Monitor genetic diversity and connectivity between SNRF study areas and between SNRF and Rocky Mountain or admixed red fox populations. | Ongoing |
| Oregon | IV.A.1.7. Determine the number of SNRF harvested annually and the proportion this harvest represents of the total SNRF population. | Not started |
| Oregon | IV.A.2.2. Identify and survey remaining gaps in coverage, including south of CLNP, between CLNP and the Central Cascades study area, and between the Central Cascades study area and Mt. Hood. | Ongoing |

| IV.B. Management Actions Recommendations | | |
|---|---|---|
| Range-wide | IV.B.1. Identify places where SNRF cross roads, especially places associated with vehicle strikes. At known SNRF crossings, implement any feasible management actions to protect SNRF from vehicle strikes, especially near den sites. | ODFW and NPS collect information on SNRF killed by vehicle strikes in the Central Cascades and CLNP study areas. Vehicle strike mortalities in California may occur but go unreported. No mitigation measures have been implemented to protect SNRF from vehicle strikes. |
| Range-wide | IV.B.2. Continue to evaluate current land use and management prescriptions and develop best land management practices to protect SNRF habitat*. | Ongoing |
| Range-wide | IV.B.2.1. Consider the potential impacts to SNRF when permitting new recreation uses or development in SNRF habitat. | Unknown |
| Range-wide | IV.B.2.2. Consider the potential impacts to SNRF when planning or permitting land uses, developments, or management activities in SNRF habitat. | Unknown |
| Range-wide | IV.B.2.3. Consider the potential impacts to small mammal prey species, particularly leporids, when planning or permitting land uses, developments, or management activities in SNRF habitat. | Unknown |
| Range-wide | IV.B.2.4. Maintain or enhance meadows in SNRF habitat within their natural range of variation, restoring or preserving hydrologic function and plant species composition. | Unknown |
| Range-wide | IV.B.2.5. To the extent consistent with fuels reduction, vegetation treatment, and thinning activities necessary for forest health and fire risk reduction, maintain elements of understory structure in forested SNRF habitat to provide cover for forest-floor-dwelling small mammal species. | Unknown |
| Range-wide | IV.B.2.6. Maintain subalpine and montane forests in SNRF habitat within their natural range of variation to support the health of mast species such as whitebark pine. | Unknown |

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|---|---|---|
| Range-wide | IV.B.2.7. When a den site is identified, coordinate with wildlife managers to determine appropriate land use, management, or recreation activities in that vicinity. | Unknown |
| Range-wide | IV.B.2.8. When issuing special use permits for events in SNRF habitat, consider the location, size, and timing of events relative to known SNRF den sites and denning season, as well as whether events will likely introduce anthropogenic food or trash into SNRF habitat. | Unknown |
| Range-wide | IV.B.3. Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation. | Ongoing |
| Range-wide | IV.B.3.1. Encourage pet owners to prevent pet aggression toward SNRF and minimize potential disease transmission by leashing pets, removing pet waste, and ensuring pets are vaccinated for common diseases such as rabies and canine distemper. | Unknown |
| Range-wide | IV.B.3.2. Discourage use of rodenticides at resorts and residences in occupied SNRF habitat. | Unknown |
| Range-wide | IV.B.3.3. Continue to provide and improve general educational materials about SNRF for the public and the media. | Ongoing |
| Range-wide | IV.B.3.4. Continue to engage the public in citizen science efforts to monitor SNRF, including by encouraging reporting of observations to appropriate managers and submission of photos if available to confirm identification. | Ongoing |
| Range-wide | IV.B.3.5. Protect sensitive location data, especially den site locations, from public knowledge. | Ongoing |
| Range-wide | IV.B.4. Reduce incidence of SNRF habituation due to availability of human food in SNRF habitat. | Unknown |

| | | |
|---|---|---|
| Range-wide | IV.B.4.1. Discourage feeding SNRF or making trash available to scavenging SNRF or other sympatric carnivores such as bears, coyotes, or gray foxes. | Unknown |
| Range-wide | IV.B.4.2. Provide carnivore-proof trash receptacles at developed recreation sites within SNRF habitat, particularly in winter and in locations where trash can accumulate, such as parking lots and campgrounds. | Unknown |
| | | |
| Oregon | IV.B.1. Identify places where SNRF cross roads, especially places associated with vehicle strikes. At known SNRF crossings, implement any feasible management actions to protect SNRF from vehicle strikes, especially near den sites. | ODFW and NPS collect information on SNRF killed by vehicle strikes in the Central Cascades and CLNP study areas. No mitigation measures have been implemented to protect SNRF from vehicle strikes. |
| | | |
| **IV.C. Planning and Collaboration Recommendations** | | |
| Range-wide | IV.C.1. Complete a translocation feasibility assessment. | Not started |
| Range-wide | IV.C.1.1. Continue genetic research to inform a range-wide genetic management plan. | A range-wide genetic management plan is in progress. |
| Range-wide | IV.C.1.2. Assess the feasibility of a captive breeding program. | Not started |
| Range-wide | IV.C.2. Create better systems to manage, store, and share SNRF data across regions and agencies. | Not started |
| Range-wide | IV.C.3. Ensure new information about the SNRF is integrated periodically into revisions or amendments to the Conservation Strategy. | Not started |
| Range-wide | IV.C.4. Improve regulatory support for range-wide SNRF conservation. | Not started |

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|---|---|---|
| Lassen | IV.C.1.3. Assess the carrying capacity of the Lassen region and identify possible release sites to facilitate translocation planning. | Current distribution and habitat modeling efforts may be able to assess the habitat suitability of possible release sites in the Lassen region. |
|  |  |  |
| Oregon | IV.C.1.3. Evaluate the potential for SNRF in Oregon to serve as source stock for future translocations. | Not started |
|  |  |  |
| Other States | IV.C.1.4. Evaluate the potential for non-SNRF montane red fox populations (such as Cascades red foxes in Washington and Rocky Mountain red foxes in Colorado) to serve as source stock for future translocations. | Unknown |

*For the purposes of these and other recommendations pertaining to land management, "SNRF habitat" is defined as areas known to be occupied by SNRF (e.g., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the historical range.

# V. CONCLUSION

In contrast to many rare, threatened, and endangered species, contemporary human actions such as destruction of habitat or human-caused mortality are not thought to be the primary factors preventing recovery of the SNRF. Instead, the main factor limiting SNRF recovery is the small size and low genetic diversity of some extant populations. This problem should be seen as an opportunity, because it can likely be addressed with minimal conflict through relatively small-scale interventions. SNRF recovery is therefore limited chiefly by the lack of information and funding needed to design and carry out such interventions, particularly in the Lassen population, where emergency reinforcement may be necessary to prevent extirpation. The most immediate priority of the Strategy is to address critical information gaps that hinder recovery action, such as documenting the full extent of the subspecies' current distribution and identifying appropriate source populations for translocations.

Some potentially beneficial management actions can proceed without further information and should be implemented in the near future. These include public education to discourage littering and feeding wildlife, implementing carnivore-proof trash disposal, reducing mortality from vehicle strikes, and mitigating disturbance to known den sites. Over the longer term, more research is needed to better understand ecological and anthropogenic threats to the SNRF, and to develop management responses to those threats. Strong partnerships between researchers and agencies have supported SNRF conservation for more than a decade, and will continue to guide research and recovery efforts.

The SNRF is a rare, vulnerable component of the native biota of the Sierra Nevada and Cascades in California and Oregon. Alpine and subalpine ecosystems typically lack the redundancy found within more biodiverse environments, such that relatively few species and subspecies contribute to a given trophic role. The loss of any part of the alpine or subalpine community has the potential to disrupt the fragile linkages between predators, prey, and primary producers that have evolved over tens of thousands of years. Within the SNRF's range, the mesocarnivore niche is already depauperate: wolverines have likely been extirpated from California, and Pacific martens may be declining in parts of their range (Zielinski et al. 2005; Moriarty et al. 2011). Despite our limited understanding of the role SNRF play in their ecosystem, it is reasonable to predict that the loss of this subspecies could greatly diminish an entire trophic level of the alpine and subalpine community. Through continued research, targeted management, and range-wide collaboration, it may be possible to prevent such a loss.

# APPENDIX A. RECOMMENDATIONS DETAILS

Where possible, we have provided a summary of the current status of each recommendation, implementation considerations, and an approximate assessment of resources needed. We assign ratings of high, medium, or low to each type of resource need (funding, staffing, time, and agency coordination). These ratings are intended as rough estimates to give a sense of the relative resource intensiveness of each recommendation, rather than precise budgets. This Strategy does not commit any agency to providing any resources. In general, these ratings should be viewed as suggestions, as numerous parameters can change the resource needs of an action.

Because the Sierra Nevada DPS of the SNRF is listed as federally endangered, some of the actions below may require additional resources and agency coordination such as consultation with USFWS, as outlined in Section 7 of the ESA, to determine whether a proposed project may "jeopardize the continued existence of any endangered species," or application for recovery permits under Section 10 to conduct scientific research through means that would otherwise be prohibited by the ESA (Endangered Species Act 1973, 1978, 1982).

Ratings are defined as follows:

**Funding Needs**
High = estimated project cost may exceed $100,000 annually
Medium = estimated project cost may range from $50,000–$99,999 annually
Low = estimated project cost may range from $0–$49,999 annually

**Staffing Needs**
High = involvement from 5+ staff, possibly from multiple partners
Medium = involvement from 2–4 staff, possibly from multiple partners
Low = involvement from 0–1 staff per partner

**Time Needed***
Ongoing = should be completed periodically on an ongoing basis
High = requires 5+ years for completion
Medium = may be completed within 2–4 years
Low = may be completed within 1 year

**This category indicates the length of time needed to complete an action, not the urgency with which the action should be initiated. Ideally, all recommended actions identified in this section should be initiated as soon as possible.*

**Agency Coordination**
High = requires coordination between 3+ partner entities
Medium = requires coordination between 2 partner entities
Low = a single entity can accomplish this task

## IV.A. INFORMATION NEEDS RECOMMENDATIONS

**IV.A.1. Range-wide:** Continue to monitor abundance, distribution, health, and genetic composition of known populations.
Current Status:

- CDFW intensively monitors the Lassen population through remote camera and scat surveys and collaring efforts.
- UC Davis, CDFW, USFS, and NPS have conducted remote camera and scat surveys over the past decade in habitat known to be occupied by SNRF.
- UC Davis concluded scat surveys in the Sonora Pass study area in 2020
- YNP will conclude SNRF surveys after 2020.
- CDFW plans to continue monitoring indefinitely via remote camera and scat collection in the Mono Creek study area and via remote camera in the Sonora Pass study area.
- CDFW will attempt SNRF captures in the Sonora Pass and/or Mono Creek study areas in future.
- ODFW, USFS, and Wildlife Ecology Institute currently monitor SNRF in the Central Cascades study area. ODFW began camera surveys in the area between the Central Cascades and CLNP study areas in 2019.
- CLNP is not currently implementing a project to specifically monitor the SNRF population in the park. A current study with USFWS and U.S. Geological Survey to determine the impacts of large fires on carnivores in the park will likely yield more information about the SNRF population in the CLNP study area. Continued efforts to find funding to support remote camera surveys, scat dog surveys, and an internship project in collaboration with Oregon State University - Cascades will continue for the foreseeable future.
- UC Davis conducts genetic analysis of scat samples.

Implementation Considerations:

- Low density, remote habitat, and elusive behavior make SNRF difficult to monitor reliably.
- Additional funding will be necessary to continue monitoring efforts indefinitely.
- To the extent feasible, unifying monitoring and data management protocols may simplify current and future monitoring and analysis efforts (see Appendix B).

**IV.A.1.1. Lassen:** Continue to monitor SNRF abundance and distribution in the Lassen Peak and Caribou Wilderness areas.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.2. Lassen:** Monitor genetic diversity and genetic effective population size and attempt to detect immigration events.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.3. Sierra Nevada:** Continue to monitor SNRF abundance and distribution in the Sonora Pass, YNP, and Mono Creek study areas.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.4. Sierra Nevada:** Monitor genetic diversity and genetic effective population size and attempt to detect immigration and dispersal events. Track rate and prevalence of genetic admixture.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.5. Oregon:** Continue to monitor SNRF abundance and distribution. Ensure monitoring methods can be used to generate population estimates.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.6. Oregon:** Monitor genetic diversity and connectivity between SNRF study areas and between SNRF and Rocky Mountain or admixed red fox populations. Monitor possible contact zones between SNRF and other red fox populations.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.1.7. Oregon:** Determine the number of SNRF harvested annually and the proportion this harvest represents of the total SNRF population.

- Reach out to furtakers to request submission of biological samples along with red fox harvest reports.

Current Status:

- While hunters and trappers in Oregon are required to report red fox harvest, there is no current method to differentiate harvested SNRF from other red fox subspecies.

Implementation Considerations:

- Harvest reporting may be difficult to implement.
- If voluntary, submitted tissue may provide an incomplete sample of red fox harvest.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: Low

**IV.A.2. Range-wide:** Conduct systematic, coordinated, extensive surveys for SNRF, following the Survey and Monitoring Guidelines in this document, in areas of suitable habitat that have not been surveyed or where SNRF have not been detected.

Current Status:

- CDFW and NPS currently collaborate on SNRF surveys as of fall 2020.
- ODFW began SNRF camera surveys along a portion of the Cascades crest between the Central Cascades and CLNP study areas in 2019.

Implementation Considerations:

- Deploying remote cameras in wilderness is essential to successful SNRF surveys. Agencies vary in their treatment of this survey method. Future surveys will be streamlined if agencies support the use of remote cameras in wilderness.

**IV.A.2.1. Sierra Nevada:** Survey high elevations (above 2,500 m) of Sequoia and Kings Canyon National Parks and areas of high habitat suitability east of the park boundaries.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: High
- Agency Coordination: High

**IV.A.2.2. Oregon:** Identify and survey apparent gaps in distribution, including south of CLNP, between CLNP and the Central Cascades study area, and between the Central Cascades study area and Mt. Hood.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: High
- Agency Coordination: High

**IV.A.3. Range-wide:** Improve understanding of SNRF vital rates, health, and resource utilization.

Current Status:

- ODFW is actively collaring SNRF in the Bend area.
- CDFW is actively collaring SNRF in the Lassen area.
- CDFW may attempt SNRF captures in the Sonora Pass and/or Mono Creek study areas in future.
- In California, tissue samples are preserved from necropsied SNRF and tissue and blood samples are collected from captured SNRF.
- In the Central Cascades study area in Oregon, tissue samples are preserved from necropsied SNRF and tissue, but not blood, samples are collected from captured SNRF.

Implementation Considerations:

- Collection of GPS location data is limited by current collar technology and inconsistent performance (e.g., battery failure, premature cessation of data logging or reporting, etc.) and the practical challenges of capturing and collaring a representative sample of SNRF.
- Sample sizes may be too small to allow for reliable estimates of vital rates.
- Current collaring studies are largely focused on basic SNRF biology, distribution and habitat use, and survival and reproduction. Additional studies specifically designed to address questions related to recreation effects, competition, or other potential threats to the SNRF may be desirable.
- When animals are captured, standard protocols are needed to ensure collection of morphological, age, sex, photographic, and health data, along with collection of high-quality genetic samples, including all of the following: ear notches, whole blood (EDTA), pulled hair, and pathogen-exposure samples.
- A shared protocol is needed between California and Oregon to coordinate analysis of biological samples.

**IV.A.3.1. Range-wide:** Assess and track SNRF individuals through captures and deployment of GPS collars.

Resource Needs:

- Funding: High
- Staffing: High
- Time: Ongoing
- Agency Coordination: Low

**IV.A.3.2. Range-wide:** Collect biological samples (tissue and/or blood) from all captured or necropsied SNRF for genetic and disease analysis. Conduct histology, PCR, serology, and toxicology testing. Perform physical exams to assess body condition of all captured SNRF. Perform full necropsies on all SNRF mortalities whenever carcass condition is suitable.

- Biological sample collection procedures should be standardized throughout the range and should ideally take place whenever SNRF tissue is available (e.g., captures, necropsies).
- Morphological, reproductive, age, sex, and body condition data collection procedures should be standardized throughout the range and should ideally take place whenever SNRF are captured.
- Analysis of samples should be coordinated to ensure consistency of interpretation.

Resource Needs:

- Funding: Medium
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.3.3. Range-wide:** Investigate home-range size, fine-scale habitat selection, seasonal habitat use, and den-site selection.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Low

**IV.A.3.4. Range-wide:** Determine reproductive rates, timing of reproduction, litter size, and juvenile recruitment rates.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Low

**IV.A.3.5. Range-wide:** Investigate mortalities to determine cause of death and estimate survival rates.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Low

**IV.A.4. Range-wide:** Assess the risk of outbreeding depression in admixed SNRF populations by identifying local adaptations of the SNRF genome.

- Collect a larger body of phenotypic data on SNRF and other red fox populations.

Current Status:

- A limited body of phenotypic data is available from live-capture studies of SNRF and other montane red fox populations.
- UC Davis has sequenced whole genomes from SNRF and other red fox populations (for the purposes of assay design)

Implementation Considerations:

- Both phenotypic and genomic methods are challenged by small sample sizes and uncertainty in the interpretation of results.

Resource Needs:

- Funding: High
- Staffing: Low
- Time: Medium-High
- Agency Coordination: High

**IV.A.5. Range-wide:** Refine SNRF distribution and habitat models.

Current Status:

- SNRF distribution and habitat were modeled range-wide by Green et al. (in preparation) and Stermer (in preparation), in California by Cleve et al. (2011), and in Oregon by Quinn et al. (2018).
- Two SNRF dens used by GPS-collared females have been located in the Lassen study area, and multiple dens have been located in the Central Cascades study area.
- Most information about SNRF habitat use is coarse-scale and inadequate to justify inferences about fine-scale habitat requirements. However, a growing body of GPS location data from collared animals may improve our understanding of SNRF habitat at multiple scales.
- To date, no studies or analyses have specifically investigated the effects of land management activities, recreation, or development on SNRF habitat, space use, den-site selection, or connectivity.

Implementation Considerations:

- Collection of GPS location data is hindered by flawed collar technology and the practical challenges of capturing and collaring a representative sample of SNRF.
- The minimal location data available for SNRF may limit inferences about habitat selection.
- The small sample size of known den sites limits inferences about habitat use and possible disturbances in the vicinity of dens.

**IV.A.5.1. Range-wide:** Assess accuracy of models by ground-truthing with survey data.

Resource Needs:

- Funding: High
- Staffing: High
- Time: Medium
- Agency Coordination: High

**IV.A.5.2. Range-wide:** Investigate the influence of land management activities (e.g., timber harvest, prescribed fire, grazing) on SNRF presence or habitat selection. Determine fine-scale characteristics that affect habitat suitability for SNRF and identify land management activities that could alter or preserve these characteristics.

Resource Needs:

- Funding: Medium
- Staffing: Medium
- Time: High
- Agency Coordination: High

**IV.A.5.3. Range-wide:** Investigate the influence of human recreation and development on SNRF presence or habitat selection.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Medium
- Agency Coordination: High

**IV.A.5.4. Range-wide:** Evaluate existing habitat connectivity for SNRF and assess the potential for habitat fragmentation. Identify barriers to connectivity or colonization.

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.5.5. Range-wide:** Determine what factors influence denning success and at what distance from den sites. Use this information to estimate reasonable buffers to protect SNRF den sites from disturbance or loss of critical habitat characteristics

Resource Needs:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.6. Range-wide:** Study sympatric carnivores (coyotes, gray foxes, martens, bobcats, mountain lions) and their distribution, abundance, habitat use, and interactions with SNRF.

Current Status:

- Coyote density in winter and summer was estimated in the Sonora Pass study area (Quinn 2018).
- Poisson et al. (2019) investigated diet niche width and overlap in coyotes and SNRF in Oregon.
- Existing remote camera data may enable analysis of sympatric carnivore occupancy.
- Existing scat data may provide insight into relative abundance or density.

Implementation Considerations:

- Noninvasive data may provide an incomplete picture of potential competitive relationships between SNRF and sympatric carnivores.
- Collection of GPS location data is hindered by flawed collar technology and the practical challenges of capturing and collaring representative samples of the populations of interest.
- Elucidating competitive relationships would likely also require a better understanding of any limiting resources.

**IV.A.6.1. Range-wide:** Estimate density, abundance, and distribution of sympatric carnivores. Identify seasonal and long-term changes in these parameters (e.g., elevational shifts in species distribution with climate change; density of other

carnivores in SNRF habitat in winter vs. summer).
Resources Needed:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.6.2. Range-wide:** Identify diet niche width and overlap for SNRF and sympatric carnivores, particularly in winter.
Resources Needed:

- Funding: Medium
- Staffing: Medium
- Time: Medium
- Agency Coordination: Medium

**IV.A.6.3. Range-wide:** Determine whether sympatric carnivores limit SNRF distribution. Assess variation in activity patterns (e.g., temporal or spatial partitioning) or occupancy of SNRF in the presence of other carnivores.
Resources Needed:

- Funding: High
- Staffing: Medium
- Time: High
- Agency Coordination: Medium

**IV.A.6.4. Range-wide:** Identify direct (e.g., predation) and indirect (e.g., competition for prey or habitat, disease transmission) impacts of sympatric carnivores on SNRF fitness.
Resources Needed:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.6.5.** Test sympatric carnivores for infection and exposure to diseases of conservation concern through necropsy of fresh mortalities or by-catch of live animals.
Resources Needed:

- Funding: High
- Staffing: High
- Time: Ongoing
- Agency Coordination: High

**IV.A.7. Range-wide:** Study effects of recreation on SNRF behavior, habitat use, survival, and reproductive success.
Current Status:

- Habituation and other effects of recreation on SNRF (e.g., interactions with domestic dogs, access to anthropogenic food or trash, proximity of dens to recreation areas) have been observed opportunistically, but no systematic studies of recreation effects have taken place to date.

Implementation Considerations:

- Because recreation activities and intensities vary by region, results would be narrowly applicable to the region studied. Some evidence also points to substantial behavioral variation among individual foxes, suggesting that even within a single region, a large sample size encapsulating that variation would be necessary to be considered representative.
- As the primary forms of motorized recreation occurring in SNRF habitat, OSV and OHV use and their effects on SNRF may be of particular interest.
- The prevalence and behavior of unleashed domestic dogs in SNRF habitat may also merit study.

**IV.A.7.1. Range-wide:** Implement recreation intensity studies to compare recreation use data (e.g., GPS tracks from recreationists) to location data from collared SNRF. Identify areas and timing of overlap and determine whether patterns of space use in SNRF appear to be influenced by type, timing, or intensity of recreation use.
Resources Needed:

- Funding: High
- Staffing: Medium
- Time: Medium
- Agency Coordination: High

**IV.A.7.2. Range-wide:** Locate SNRF dens and assess their proximity to recreation activities.
Resources Needed:

- Funding: High
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.7.3. Range-wide:** Assess the level of habituation in each SNRF population or study area. Record instances of apparent habituation and estimate the number of habituated individuals.

Resources Needed:
- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: High

**IV.A.7.4. Range-wide:** Identify sources and amounts of trash or human food available to SNRF and determine the main vectors for habituation (e.g., parking lots, campgrounds, resorts, backcountry use areas). In areas where habituation has been documented, assess the efficacy of current methods for collecting, storing, and removing anthropogenic food or trash.

Resources Needed:
- Funding: Low
- Staffing: Low
- Time: Low
- Agency Coordination: High

**IV.A.7.5. Range-wide:** Document interactions between domestic dogs and SNRF or other wildlife.

Resources Needed:
- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: High

**IV.A.7.6. Range-wide:** Evaluate success of methods used to deter or relocate habituated SNRF or similar species.

Resources Needed:
- Funding: Medium
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.A.8. Range-wide:** Determine sources and availability of SNRF food, particularly during winter and spring, including reliance on human food.

Current Status:
- Perrine (2005) and CDFW (unpublished data) studied diet in the Lassen population.
- Poisson et al. (2019) characterized SNRF diet in Oregon and overlap in diet with sympatric coyotes.

Implementation Considerations:
- Estimating prey abundance or density would likely require dedicated study independent of other research questions.
- Although diet studies would be most informative if focused on the winter and spring, scat collection and surveys for prey species would be more challenging during the snowy months.
- The most efficient method of determining diet composition is through metagenomic analysis of scat and stable isotope analysis of hair samples.
- Diet analysis could be performed on samples submitted as part of ongoing scat and hair-snare surveys for demographic and genetic monitoring.
- Abundance and density of prey could be estimated through transect surveys or live-capture studies.
- Prey occupancy might be possible to estimate using remote camera data.

**IV.A.8.1.** Perform diet analysis (e.g., metagenomic or stable isotope analysis) of scat and hair samples collected during ongoing monitoring.

Resources Needed:
- Funding: Medium
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.8.2.** Determine reliance of SNRF on leporid prey, particularly in winter. Estimate occupancy and abundance of leporids in SNRF habitat and identify any impacts of RHDV-2.

Resources Needed:
- Funding: High
- Staffing: High
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.8.3.** Determine SNRF use of or reliance on carrion killed by other carnivores.

Resources Needed:
- Funding: Medium
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.A.8.4.** Document the prevalence of anthropogenic food or trash in the diet of habituated SNRF and identify possible sources.
Resources Needed:
- Funding: Medium
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

## IV.B. MANAGEMENT ACTIONS RECOMMENDATIONS

**IV.B.1. Range-wide, Oregon:** Identify places where SNRF cross roads, especially places associated with vehicle strikes. At known SNRF crossings, implement any feasible management actions to protect SNRF from vehicle strikes, especially near den sites.
- When crossings are identified, consult with transportation authorities on the feasibility of reducing speed limits, installing signage, or constructing wildlife crossing structures in areas where SNRF have been struck by vehicles or are known to cross roads.

Current Status:
- ODFW has identified at least 1 SNRF crossing on the Cascade Lakes Highway near Mt. Bachelor.

Implementation Considerations:
- The feasibility of potential management actions is unknown and effectiveness may vary.
- SNRF crossing locations may change over time.

Resource Needs:
- Funding: Medium
- Staffing: Low-Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.B.2. Range-wide:** Continue to evaluate current land use and management prescriptions and develop best land management practices to protect SNRF habitat[12].
Current Status:
- The SNRF is designated as a sensitive species on National Forest lands, is state-threatened in California, and is identified as an Oregon Conservation Strategy Species. Accordingly, land and wildlife management activities on public lands are analyzed for potential impacts to the SNRF. However, the utility of these analyses is questionable due to uncertainty about the specific habitat attributes selected for by SNRF. The impacts of land management activities in SNRF habitat are uncertain and current management prescriptions may or may not be effective in preserving desirable habitat characteristics for SNRF.

Implementation Considerations:
- Without a better understanding of SNRF habitat selection, it is challenging to make specific recommendations for land management prescriptions tailored to protect SNRF habitat.

**IV.B.2.1. Range-wide:** Consider the potential impacts to SNRF when permitting new recreation uses or development in SNRF habitat. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3. Rodenticides, and III.A.7. Recreation, Habituation, and Development. If feasible, minimize new recreational uses or developments, such as roads, trails, parking lots, campgrounds, resorts, and OHV or OSV areas, that would result in substantially increased human or motor vehicle presence in areas used by SNRF.
Resource Needs:
- Funding: Low
- Staffing: Low-Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.2.2. Range-wide:** Consider the potential impacts to SNRF when planning or permitting land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in sections III.A.2. Vehicle Strikes, III.A.3. Rodenticides, III.A.8. Food Availability, and III.A.12. Land Use and Management. If feasible, minimize land uses or developments that would result in substantially

increased human or motor vehicle presence in SNRF habitat.
Resource Needs:

- Funding: Low
- Staffing: Low-Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.2.3. Range-wide:** Consider the potential impacts to small mammal prey species, particularly leporids, when planning or permitting land uses, developments, or management activities in SNRF habitat. These potential impacts are discussed in detail in section III.A.12. Land Use and Management, and include loss of habitat due to removal of forest understory structure or to tree and shrub encroachment in meadow habitats.
Resource Needs:

- Funding: Low
- Staffing: Low-Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.2.4. Range-wide:** Maintain or enhance meadows in SNRF habitat within their natural range of variation, restoring or preserving hydrologic function and plant species composition.
Resource Needs:

- Funding: Medium-High
- Staffing: Medium-High
- Time: Ongoing
- Agency Coordination: Low

**IV.B.2.5. Range-wide:** To the extent consistent with fuels reduction, vegetation treatment, and thinning activities necessary for forest health and fire risk reduction, maintain elements of understory structure in forested SNRF habitat to provide cover for forest-floor-dwelling small mammal species.
Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Low

**IV.B.2.6. Range-wide:** Maintain subalpine and montane forests in SNRF habitat within their natural range of variation to support the health of mast species such as whitebark pine.
Resource Needs:

- Funding: Low
- Staffing: Low-Medium
- Time: Ongoing
- Agency Coordination: Low

**IV.B.2.7. Range-wide:** When a den site is identified, coordinate with wildlife managers to determine appropriate land use, management, or recreation activities in that vicinity. Because data on active den sites are too limited currently to inform estimates of the area that constitutes the vicinity of a den, land and wildlife managers should work together to determine an appropriate buffer, keeping in mind that SNRF may use more than 1 den site during the period of pup dependency and may travel relatively long distances away from den sites.
Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: Medium

**IV.B.2.8. Range-wide:** When issuing special use permits for events in SNRF habitat, consider the location, size, and timing of events relative to known SNRF den sites and the period of increased vulnerability during denning season (at minimum, late pregnancy through the pre-weaning period, roughly April 1–August 1), as well as whether events will likely introduce anthropogenic food or trash into SNRF habitat.
Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.3. Range-wide:** Educate the public to reduce negative human-SNRF interactions and build popular enthusiasm for SNRF conservation
Current Status:

- Some general educational materials about SNRF are currently available through CDFW, NPS, ODFW, USFS, USFWS, and other sources, but many of these materials are out-of-date.

- In the Bend region of Oregon, ODFW presents educational programs about SNRF in local schools.
- Citizen science monitoring efforts for SNRF occur in the Central Cascades and CLNP study areas of Oregon.

Implementation Considerations:

- Without costly and logistically challenging enforcement, measures to reduce negative human-SNRF interactions would necessarily be voluntary, and may not be universally adopted by the public.

**IV.B.3.1. Range-wide:** Encourage pet owners to prevent pet aggression toward SNRF and minimize potential disease transmission by leashing pets, removing pet waste, and ensuring pets are vaccinated for common diseases such as rabies and canine distemper.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: High

**IV.B.3.2. Range-wide:** Discourage use of rodenticides at resorts and residences in occupied SNRF habitat.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: Low

**IV.B.3.3. Range-wide:** Continue to provide and improve general educational materials about SNRF for the public and the media.

Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.3.4. Range-wide:** Continue to engage the public in citizen science efforts to monitor SNRF, including by encouraging reporting of observations to appropriate managers and submission of photos if available to confirm identification.

Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.B.3.5. Range-wide:** Protect sensitive location data, especially den site locations, from public knowledge.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: High

**IV.B.4. Range-wide:** Reduce incidence of SNRF habituation due to availability of anthropogenic food or trash in SNRF habitat.

Current Status:

- Carnivore-proof trash receptacles are likely already present at many developed recreation sites in SNRF habitat, particularly in National Parks and in some developed campgrounds on National Forests.

Implementation Considerations:

- Recommendations or regulations against littering or feeding wildlife may be difficult to enforce, especially in areas without regular staff presence.

**IV.B.4.1. Range-wide:** Discourage feeding SNRF or making trash available to scavenging SNRF or other sympatric carnivores such as bears, coyotes, or gray foxes.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Ongoing
- Agency Coordination: High

**IV.B.4.2. Range-wide:** Provide carnivore-proof trash receptacles at developed recreation sites within SNRF habitat, particularly in winter and in locations where trash can accumulate, such as parking lots and campgrounds.

Resource Needs:

- Funding: Medium-High
- Staffing: Low
- Time: Low

- Agency Coordination: Low

# IV.C. PLANNING AND COLLABORATION RECOMMENDATIONS

**IV.C.1. Range-wide:** Complete a translocation feasibility assessment.
- Secure funding for a translocation feasibility assessment.
- Develop a timeline and task a team with creating the assessment.
- Identify remaining obstacles to moving forward with translocations (limited knowledge of threats/vital rates/current population sizes and distributions, funding needs, monitoring needs, social and political constraints, etc.).
- Prioritize recipient populations and release locations.
- Identify possible source populations.
- Develop quantitative goals for SNRF translocations.

Current Status:
- This strategy contains a preliminary discussion of translocation and captive breeding options.
- A genetic management plan is in progress and will be appended to this Strategy.
- Current distribution and habitat modeling efforts may be able to assess the habitat suitability of possible release sites in the Lassen Peak region.

Implementation Considerations:
- More information about potential source populations for translocations or a captive breeding colony is a prerequisite to any translocation effort. Before any population can be considered as potential source stock, the SCAT or Translocation Feasibility Assessment team must develop criteria to establish whether a population can provide translocation stock without undue negative effects.
- The establishment of new relationships may be necessary to enable information-sharing about potential source populations with wildlife management and research agencies in Washington, Colorado, or other states.
- Our understanding of the genetic structure of SNRF populations continues to change as more samples are collected and analyzed. Genetic management planning must regularly take new findings into account, potentially altering models and interpretation.
- Without a better understanding of SNRF habitat selection, prey requirements, and population dynamics, it may be difficult to evaluate carrying capacity.
- Anticipated climate change will likely affect habitat suitability of release locations in the future.

Resource Needs:
- Funding: High
- Staffing: High
- Time: Medium
- Agency Coordination: High

**IV.C.1.1. Range-wide:** Continue genetic research to inform a range-wide genetic management plan.
- Develop additional models as needed to explore the potential genetic consequences of various translocation scenarios.

Resource Needs:
- Funding: High
- Staffing: Low-Medium
- Time: Low-Medium
- Agency Coordination: High

**IV.C.1.2. Range-wide:** Assess the feasibility of a captive breeding program.
- Evaluate whether a captive breeding program

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[12] For the purposes of these and other recommendations pertaining to land management, “SNRF habitat” is defined as areas known to be occupied by SNRF (i.e., where SNRF detections have occurred; see Figure 1), or identified by distribution models as highly suitable habitat within the historical range (e.g., Green et al. in preparation; Stermer in preparation). These recommendations are intended to apply only within SNRF habitat.

would be feasible as an alternative to or in addition to translocating wild-caught individuals.

Resource Needs:
- Funding: High
- Staffing: High
- Time: Medium
- Agency Coordination: High

**IV.C.1.3. Lassen:** Assess the carrying capacity of the Lassen Peak region and identify possible release sites to facilitate translocation planning.
- Improve distribution and habitat models to better characterize SNRF habitat selection.

Resource Needs:
- Funding: Medium
- Staffing: Low-Medium
- Time: Low
- Agency Coordination: Low

**IV.C.1.4. Oregon:** Evaluate the potential for SNRF in Oregon to serve as source stock for future translocations.
- Develop population estimates for Oregon SNRF.
- Evaluate population viability under a variety of translocation scenarios.

Resource Needs:
- Funding: Low
- Staffing: Low-Medium
- Time: Low-Medium
- Agency Coordination: Low-Medium

**IV.C.1.5. Other States:** Evaluate the potential for non-SNRF montane red fox populations (such as Cascades red foxes in Washington and Rocky Mountain red foxes in Colorado) to serve as source stock for future translocations.
- Develop criteria to establish whether a red fox population can provide translocation stock without undue negative effects.
- Develop population estimates for potential source populations.
- Evaluate population viability under a variety of translocation scenarios.

Resource Needs:
- Funding: High
- Staffing: High
- Time: Medium-High
- Agency Coordination: High

**IV.C.2. Range-wide:** Create better systems to manage, store, and share SNRF data across regions and agencies.
- Create a unified protocol for SNRF data management and a centralized location for data storage.
- Establish data-sharing agreements among entities with SNRF data.
- Create a process by which SNRF Working Group or SCAT can collaboratively vet future proposals for analyses of SNRF data.

Current Status:
- Each agency and researcher currently manages SNRF data independently.

Implementation Considerations:
- Each agency may have different data management needs.
- Some agencies or researchers may wish to maintain exclusive control over their SNRF data until publication of manuscripts.

Resource Needs:
- Funding: Low
- Staffing: Low
- Time: Medium
- Agency Coordination: High

**IV.C.3. Range-wide:** Ensure new information about the SNRF is integrated periodically into revisions or amendments to the Strategy.
- Schedule annual in-person meeting at a time and place that is accessible to the majority of the SCAT and/or SNRF Working Group.
- Create a team charged with revisions or updates to the Strategy following each annual meeting.

Current Status:
- The SCAT plans to solicit new data annually and meet periodically to discuss needed revisions.

Implementation Considerations:
- When the Strategy is distributed, readers should be pointed to the website rather than a physical document to ensure the most up-to-date version is accessed.

Resource Needs:

- Funding: Low
- Staffing: Medium
- Time: Ongoing
- Agency Coordination: High

**IV.C.4. Range-wide:** Improve regulatory support for range-wide SNRF conservation.

- Provide recommendations for delineating the SNRF population into DPSs based on the most up-to-date understanding of connectivity and differentiation of SNRF populations.
- Where possible, seek to address the range-wide conservation needs of the SNRF rather than basing conservation planning on current DPS designations or agency jurisdictions.

Current Status:

- Numerous agencies and entities participate in research, analysis, and management of SNRF and their habitat.
- In 2015, USFWS recognized 2 DPSs of the SNRF: the Southern Cascades DPS (encompassing the Oregon and Lassen populations) and the Sierra Nevada DPS (a population centered around Sonora Pass in California). The most current information about SNRF distribution and genetic structure indicates that all 3 populations are likely equally disjunct.
- In 2021, USFWS listed the Sierra Nevada DPS of the SNRF as endangered. The Southern Cascades DPS was found not to warrant listing. However, substantial evidence suggests the Lassen population of the Southern Cascades DPS is extremely vulnerable to extirpation.

Resource Needs:

- Funding: Low
- Staffing: Low
- Time: Low
- Agency Coordination: High

# APPENDIX B. SURVEY AND MONITORING GUIDELINES

## PURPOSE AND SCOPE

The purpose of these guidelines is to provide generalized best practices for designing and conducting range-wide SNRF presence/absence surveys and population monitoring. We recognize that current study efforts vary widely in their objectives, the resources available to them, and the accessibility of their study areas, and that the methods best suited to each study will also vary accordingly. Detailed protocols for SNRF surveys are beyond the scope of these guidelines, as are recommendations for designing intensive ecological studies, such as of habitat, prey, competitor, predator, or wildlife-human relationships. Instead, we offer a framework for categorizing SNRF survey and monitoring objectives, insight into approaches that have proven successful, and caveats about the limitations of certain methods.

This guide is intended primarily to serve wildlife managers whose task is to manage entire populations or species, as well as land managers whose task is to survey particular geographically defined units, such as managed National Forests, wilderness areas, National Parks, designated recreation or training areas, or private lands. Because of the low density and wide-ranging behavior of montane red foxes, both motivations require the population, as opposed to a human-defined spatial unit, to be the survey or monitoring target.

Survey or monitoring objectives for SNRF fall into 3 general categories:

1. Determining occurrence of SNRF in portions of the historical range where their current presence is unknown (presence/absence surveys);
2. Determining the status of a known extant population (monitoring surveys); and
3. Identifying the extent and bounds of a known population's distribution and monitoring for dispersal or expansion (sentinel surveys).

Below we discuss considerations specific to each of these survey types.

## PRESENCE/ABSENCE SURVEYS

As detailed in section III.B.1. Information Needs: Tier 1, large areas of the historical SNRF range have not been surveyed in recent decades and represent an important gap in our knowledge of contemporary SNRF distribution. Extensive surveys are urgently needed to document whether and where SNRF occur in these areas. Such surveys can provide occurrence data for multiple species in addition to SNRF, including other montane carnivores whose presence may be of interest to managers.

Methods most applicable to this objective are those with high probabilities of detection and for which probabilities of detection can be quantified. Ideally, presence/absence surveys should be employed as systematically as possible to gain information from failure to detect SNRF as well as from detections. However, estimates of probability of detection serve more as a guide to survey design than as a robust means of concluding absence. That is, conducting a systematic survey and failing to detect SNRF does not necessarily imply strong evidence of their absence in the survey area. Indeed, remote camera surveys have failed to detect SNRF in areas where they were known to occur (Perrine 2005; Zielinski et al. 2005).

Broad-scale delineation of focal areas for systematic presence/absence surveys should be based on the most current models of SNRF distribution and habitat associations. Historical or recent observations, expert opinion, safety, and accessibility may also inform the selection of sampling areas.
Systematic remote camera surveys can attain high probabilities of detection for SNRF (Hiller et al. 2015; Hatfield et al. 2020; CDFW, unpublished data; NPS, unpublished data). Following an occupancy-based sampling design (e.g., Zielinski and Kucera 1995) promotes relatively even distribution of cameras across the study area. Some previous camera surveys for SNRF in California have used a grid of 10.4-km2 hexagonal cells to divide the landscape into sampling units, with a minimum of 2 cameras per cell spaced a minimum of 1.6 km apart. However, it is important to recognize that recent research indicates the effective sampling area of a camera is much smaller than the grid cell size (Burton et al. 2015; Wilton et al. 2016; Tucker et al. in review). Consequently, 2 widely spaced cameras may operate as point-sampling devices rather than sampling an entire cell, which can greatly reduce the scope of inference for a survey. If logistics and access allow, spacing out multiple cameras within a cell can increase the effective area of surveys.

Preliminary data from studies in California indicate that SNRF may be most detectable by remote cameras in the fall, winter, and spring (Hatfield et al. 2020; CDFW, unpublished data; C. Quinn, UC Davis, unpublished data; NPS, unpublished data). During these seasons, animal movement across the landscape is often constrained by deep snow, which may make SNRF more likely to be detected by cameras placed in travel corridors (passes or windswept ridges) with little or no snow. Prey availability is also likely more limited during these seasons, perhaps increasing the attraction of SNRF to bait or lure.

Other measures to increase probability of detection include maximizing the length of time during which cameras are operational and optimizing microsite selection for camera placements. In the Mono Creek study area in 2018, days from camera deployment to first SNRF detection averaged 132 with a range from 47 to 223 (B. Hatfield, CDFW, unpublished data). This suggests placing cameras in a single location for an extended period of time may be an effective strategy for detecting animals like SNRF with large home ranges and extensive daily movements. Green et al. (in preparation) also found that SNRF were more likely to be detected at cameras deployed for longer periods of time.

Surveying during the winter months also necessitates measures taken to reduce the risk of camera burial by snow, especially in locations that cannot be revisited regularly to ensure proper camera function. At and above treeline, camera sites that are exposed to prevailing winds are less likely to be buried in snow. Selecting for topography that creates wind-scoured features like narrow passes and barren ridges can also reduce the risk of snow accumulation affecting camera operation. Such topographic features can also function as travel corridors, effectively funneling animals past a camera station rather than relying solely on individual behavior to prompt animals to enter the camera frame. In the Mono Creek study area in 2018, 86% of detections occurred at cameras located on alpine passes or ridges (B. Hatfield, CDFW, unpublished data). Green et al. (in preparation) found that SNRF were less likely to be detected at cameras deployed on steep slopes and more likely to be detected at cameras deployed on barren ground.

In more vegetated areas below treeline, landscape features associated with successful camera placements include:

- Sites near or along commonly used animal trails
- Forest edge at treeline
- Forest edge surrounding a meadow complex or lake

A variety of lures and baits have been used to attract SNRF to camera stations. Contemporary surveys typically use a commercial trapping lure called Gusto (Minnesota Trapline Products, Pennock, Minnesota) and/or chicken legs as bait. Accessibility of camera locations may dictate the type of attractant applied, and lure without bait has been effective at attracting SNRF in remote alpine survey areas up to several months after application (Hatfield et al. 2020). Green et al. (in preparation) found that SNRF were less likely to be detected if bait was used at camera stations, while use of lure at camera stations did not affect detectability.
If remote cameras detect red foxes, researchers should follow up with scat surveys, as described below, in areas with detections to obtain genetic samples for subspecies and individual identification.

## MONITORING SURVEYS

The particular characteristics of SNRF, including naturally low population densities, large home-range sizes, and hesitancy to enter enclosed spaces (e.g., track plate or hair snare devices), necessitate special considerations not adequately addressed by protocols designed to survey for or monitor other mesocarnivores, such as forest mustelids (e.g., Zielinski and Kucera 1995). Below we evaluate several methods for monitoring SNRF populations. We recommend occupancy approaches (as described under Presence/Absence Surveys and Sentinel Surveys) when the goal is to detect new populations or population expansion, but individual-based methods when the goal is monitoring known populations.

Monitoring the status of extant small SNRF populations (e.g., < 50 individuals) involves several objectives that can be met most efficiently by employing multiannual individual-based noninvasive genetic surveys (MINGS), specifically using DNA from scats to enumerate individuals and document the following characteristics of each:

1. Sex
2. Age
3. Familial relationships to others
4. Minimum reproductive output
5. Minimum survival
6. Resident or immigrant (and, if the latter, population of origin)
7. Composition of ancestry

For known small populations and new detections (when at least one individual has been discovered in a study area), the presumption should be of a small population to be assessed through monitoring surveys. Monitoring should be conducted every year and in the same sites, particularly in areas found to contain established breeding pairs during past surveys.

The general rationale for monitoring surveys is laid out by Gerber et al. (2014:463–470). They describe well the circumstances surrounding monitoring surveys for SNRF, specifically infrequent detections of small numbers of individuals requiring long sampling durations with heterogeneous detections. The goal in these surveys is essentially to perform complete censuses of the population by increasing the probability of detection to as close to 100% as possible, which is accomplished by obtaining at least 2–3 genetic samples for every individual. Capture frequencies (i.e., numbers of genetic samples) are used to assess confidence in having sampled adequately. A population that has been determined to number more than 50 individuals will require modifications that relax requirements to sample 100% of individuals.

Among the multiple types of noninvasive DNA samples, scats are the preferred source and surveys should be designed specifically around scat collection. Hair also provides DNA and can be collected opportunistically using baited hair snares, but is highly susceptible to individual behavior (i.e., trap-happy and trap-shy individuals), which can vary tremendously in small fox populations. The most thorough and efficient scat surveys are possible in the late summer and early fall, when high elevation areas are most accessible and weather conditions most conducive to DNA preservation in scats. Late summer and fall also represent the season when young of the year are first mobile, making this an ideal time for annual post-breeding surveys. Winter surveys, particularly those done in tandem with other activities such as presence/absence surveys or sentinel surveys, are also useful and can enable collection of urine or tracks in snow for eDNA analysis.

Non-individual based approaches that utilize multiple alternative data sources (remote cameras, scat surveys, GPS collar data) have been used to estimate abundance and density in some small populations (e.g., < 50 individuals; Chandler and Royle 2013; Sollman et al. 2013). However, for SNRF, which occur at low densities and occupy large home ranges in rugged terrain, sampling to inform such approaches would need to be as or more intensive than for individual-based noninvasive genetic monitoring methods, and the integration of individual-based data would improve the precision of multimethod models (e.g., Furnas et al. 2018).

For larger populations where a complete census is not feasible, occupancy-based approaches are commonly employed to monitor the status of known populations. For example, martens occur over such a wide range and in sufficiently large numbers that estimates of their range-wide abundances are infeasible. Instead, monitoring occupancy over a network of survey sites provides indicators of range decline that can alert to demographic problems. This approach of using occupancy as a surrogate for abundance is relatively inexpensive, logistically appealing, and statistically well established (MacKenzie et al. 2017). However, several issues arise in applying occupancy to indirectly monitor the status of very small populations such as those of the SNRF. The first is an issue of statistical power, in which large sample sizes are necessary to detect trends of even moderate to large effect (e.g., 20–50% decline over 10 years; Zielinski and Stauffer 1996; Zielinski et al. 2013). Most known SNRF populations occur in very restricted ranges with small numbers of individuals. Monitoring occupancy in a known population to detect distributional changes would typically be too insensitive to detect population declines with enough time to enable a management response. Second, the relationship between occupancy and abundance varies significantly by sampling design (e.g., the spatial grain and duration of surveys) and species-specific life history traits (e.g., density, home-range size; Efford and Dawson 2012; Steenweg et al. 2018). This variability makes interpreting changes in occupancy challenging in all species, but particularly so in rare and declining populations for which occupancy-abundance relationships are the weakest and behave most unpredictably (Hartley and Kunin 2003; Webb et al. 2007). Generally, the less linear the relationship, the more abundance can fluctuate without registering as a change in occupancy.

Finally, genetic and demographic factors such as the genetic integrity of populations, reproduction, or lifespan of individuals are difficult to monitor using traditional occupancy survey approaches. Thus, for SNRF, occupancy approaches are most appropriate for finding new populations (presence/absence) or monitoring the periphery of known populations for expansion (sentinel surveys), whereas focal methods that produce data on demographic and genetic status are most appropriate for monitoring known populations.

If non-individual-based approaches are used to monitor SNRF populations, key sampling design factors for effective monitoring of trends include:

- Consistent sampling locations over time (i.e., survey devices are deployed in fixed locations within each grid cell, and identical grid cells are repeatedly sampled over time). Monitoring in fixed locations over time is critical to minimize variation in population estimates, enabling detection of trends, and to maximize the ability to link changes in environmental covariates to changes in occupancy. Resampling identical grid cells over time also greatly increases the power to detect trends (Tucker et al. 2019).
- Moderate probabilities of detection. Tucker et al. (2019) found their ability to detect population declines in fishers and martens was extremely limited when probability of detection was less than 10% or effective sampling area was small. Probability of detection and effective sampling area can be increased by including more than one device at each sampling location (e.g., a paired set of cameras in close proximity), by deploying arrays of multiple cameras spaced within a cell (e.g., 3 cameras spaced 1.6 km apart), or by extending the period of time over which cameras are deployed.

## SENTINEL SURVEYS

Sentinel surveys are periodic assessments of areas at the periphery of known SNRF distribution to detect dispersal and range expansion. These surveys are essentially hybrids between presence/absence surveys designed to document occurrence in portions of the range where SNRF are not known to exist, and monitoring surveys, where presence is known. Ideally, sentinel surveys should be systematic and use methods that provide a sufficiently high detection probability to detect trends, but sampling can be more ad hoc than in monitoring surveys.

Remote cameras are likely the most feasible sampling tools to achieve appropriate detection probabilities in sentinel survey areas. Sentinel surveys should prioritize suitable habitat (as identified by distribution and habitat models) adjacent to areas known to be occupied by SNRF. As with presence/absence surveys, standardized grid cells provide a helpful framework to space sampling devices across the landscape, and survey design should maximize the duration of sampling and optimize the placement of individual cameras.

If remote cameras in sentinel areas detect red foxes, those areas can be added to the areas sampled during monitoring surveys and the sentinel survey zone can be expanded to the next adjacent set of unoccupied grid cells. Scat samples should be obtained from sentinel cells with detections and compared to known individuals in the core of the range to determine whether new detections represent offspring, as in an expanding population, or new individuals, as might occur if a portion of the population was present previously but undetected.

## OPPORTUNITIES FOR TESTING AND IMPROVEMENT OF METHODS

As more data are collected and methods are refined, it may become possible to test assumptions inherent in current survey designs. Below we enumerate elements of current methods that could benefit from additional testing and refinement in future:

- Probabilities of detection for remote cameras in different seasons (winter, summer, year-round)
- Effects of bait and lure on probability of detecting SNRF (bait only, lure only, bait and lure, no bait or lure)
- Effective sampling area of remote cameras (e.g., deploy systematic camera survey in an area with GPS-collared individuals)
- Grid cell size
- Number of cameras per grid cell
- eDNA snow sampling methods for urine and snow tracks

In addition, a unified data collection system would aid in aggregating or tracking surveys completed across multiple groups (see III.D.1. Planning and Collaboration: Coordination Between Agencies and Researchers).

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# APPENDIX C. SCIENTIFIC NAMES

| Mammals | |
|---|---|
| **Common Name** | **Scientific Name** |
| (American) badger | *Taxidea taxus* |
| (American) black bear | *Ursus americanus* |
| Arctic fox | *Vulpes lagopus* |
| Black-footed ferret | *Mustela nigripes* |
| Bobcat | *Lynx rufus* |
| Canada lynx | *Lynx canadensis* |
| Cascades red fox | *Vulpes vulpes cascadensis* |
| Coyote | *Canis latrans* |
| Deer mouse | *Peromyscus spp.* |
| Ethiopian wolf | *Canis simensis* |
| Golden-mantled ground squirrel | *Callospermophilus lateralis* |
| Gray fox | *Urocyon cinereoargenteus* |
| (Gray) wolf | *Canis lupus* |
| Island fox | *Urocyon littoralis* |
| Kit fox | *Vulpes macrotis* |
| Long-tailed vole | *Microtus longicaudus* |
| Meadow vole | *Microtus pennsylvanicus* |
| Mexican wolf | *Canis lupus baileyi* |
| Mountain lion | *Puma concolor* |
| Mule deer | *Odocoileus hemionus* |
| Navajo Mogollon vole | *Microtus mogollonensis navaho* |
| Ocelot | *Leopardus pardalis* |
| (Pacific) fisher | *Pekania pennanti* |
| (Pacific) marten | *Martes caurina* |
| Pocket gopher | *Thomomys spp.* |
| Red squirrel | *Tamiasciurus hudsonicus* |
| Rocky Mountain red fox | *Vulpes vulpes macroura* |
| Sacramento Valley red fox | *Vulpes vulpes patwin* |
| Santa Catalina Island fox | *Urocyon littoralis catalinae* |
| Sierra Nevada red fox | *Vulpes vulpes necator* |
| Snowshoe hare | *Lepus americanus* |
| (Southern) red-backed vole | *Myodes gapperi* |
| Swift fox | *Vulpes velox* |

| | |
|---|---|
| Thirteen-lined ground squirrel | *Ictidomys tridecemlineatus* |
| Trowbridge's shrew | *Sorex trowbridgii* |
| Western red-backed vole | *Myodes californius* |
| White-tailed jackrabbit | *Lepus townsendii* |
| Wolverine | *Gulo gulo* |
| Yellow-bellied marmot | *Marmota flaviventris* |
| Yellow-pine chipmunk | *Tamias amoenus* |

| **Plants** | |
|---|---|
| **Common Name** | **Scientific Name** |
| Jeffrey pine | *Pinus jeffreyi* |
| Lodgepole pine | *Pinus contorta* |
| Manzanita | *Arctostaphylos spp.* |
| Mountain hemlock | *Tsuga mertensiana* |
| Noble fir | *Abies procera* |
| Pacific silver fir | *Abies amabilis* |
| Ponderosa pine | *Pinus ponderosa* |
| Red fir | *Abies magnifica* |
| Subalpine fir | *Abies lasiocarpa* |
| White fir | *Abies concolor* |
| Whitebark pine | *Pinus albicaulis* |

| **Birds** | |
|---|---|
| **Common Name** | **Scientific Name** |
| Golden eagle | *Aquila chrysaetos* |
| Sooty grouse | *Dendragapus fuliginosus* |

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