Species Status Assessment Report

for the

California Spotted Owl

(*Strix occidentalis occidentalis*)



Photo provided by Tim Dermers

Version 2.0
November 2022

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EXECUTIVE SUMMARY

We, the U.S. Fish and Wildlife Service (Service), were petitioned to list the California spotted owl (CSO) as endangered or threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543) (Act), in December 2014 by the Wild Nature Institute and John Muir Project of Earth Island Institute and again in August 2015 by Sierra Forest Legacy and Defenders of Wildlife. In September 2015, the Service published a 90-day finding that the petition presented substantial scientific or commercial information indicating that listing CSO may be warranted (80 FR 56423, September 18, 2015). In November 2019, the Service published a 12-month finding in the Federal Register that listing CSO was not warranted (84 FR 60371, November 8, 2019). In August 2020, Sierra Forest Legacy, Defenders of Wildlife, and the Center for Biological Diversity filed a complaint challenging our 12-month finding that listing was not warranted. On November 30, 2021, the Service voluntarily remanded the not warranted finding and committed to a deadline of February 15, 2023, for submitting to the Federal Register a 12-month finding on CSO. Therefore, a review of the status of the subspecies was initiated to determine if listing is warranted. Based on the status review, the Service will issue a 12-month finding for CSO.

This report summarizes the results of the Species Status Assessment (SSA) completed for the California spotted owl. To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 Rs). These principles rely on assessing the species at an individual, population, and species level to determine whether the species can maintain its persistence into the future and avoid extinction by having multiple resilient populations distributed widely across its range. California spotted owls are currently found throughout their known historical range, although there is evidence of a decrease in abundance in parts of the range. California spotted owls are distributed across habitat in California and Nevada including the Sierra Nevada, coastal California, and southern California. We identified two CSO populations: one in the Sierra Nevada (likely to be a continuously distributed population), and another in coastal and southern California (likely to be several disjoint subpopulations; hereafter referred to as the coastal-southern California population). Available demography data indicate that the California spotted owl may be more or less resilient in different portions of the species range. For our analysis we further divided each of the two populations into analysis units based on land management boundaries, with 11 analysis units in the Sierra Nevada population and 4 analysis units in the coastal-southern California population. For California spotted owl, resiliency was measured by assessing the individual needs of canopy cover, large trees, and habitat heterogeneity, as well as the population needs of dispersal, survival, fecundity, occupancy, and population growth. At the species level, we assess redundancy and representation throughout the entire CSO range to better understand the viability of the species.

Our analysis of the past, current, and future influences on the California spotted owl revealed that there are several factors that contribute to the current condition and pose a risk to future viability of the species. These risks include large-scale high-severity fire, tree mortality, effects of climate change, fuels reductions and forest management, barred owls, rodenticides, development, and regulatory mechanisms and other management actions. Parasites, disease, and recreation are not currently known to have population level impacts on the California spotted owl, but these risks are discussed in the future condition sections as we expect potential changes in these influences in the future. Under current conditions, the California spotted owl has three analysis units that are stable, seven analysis units that are in declining condition, and five analysis units that are in strongly

declining condition, resulting in the Sierra Nevada population having low resiliency and the coastal-southern California population having very low resiliency.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the California spotted owl. If populations lose resiliency, they are more vulnerable to extirpation, with resulting losses in representation and redundancy. The rates at which future stressors may act on specific populations or analysis units and the long-term efficacy of current conservation actions (i.e., conservation strategies) are unknown. Therefore, we forecasted how possible future conditions could impact the resiliency, redundancy, representation, and overall condition of the California spotted owl. To assess future condition, we have developed two future plausible scenarios. The following is a description of the two future scenarios, the status of the California spotted owl when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1: Factors that are currently having an influence on California spotted owl populations and analysis units increase in both trend and magnitude, with implemented management efforts having mixed success in addressing those threats. Under Scenario 1, we project the California spotted owl would have zero analysis units in stable condition, four analysis unit that are in declining condition, six analysis units that are in strongly declining condition, and five analysis units that are extirpated.

1. Large-scale high-severity fires increase on the landscape throughout California spotted owl habitat.
2. Tree mortality numbers increase in the future due to drought, disease, and beetles.
3. Drought conditions increase in the future, resulting in both habitat impacts and physiological impacts to California spotted owls.
4. Effects of climate change increase in the future, resulting in both habitat impacts and physiological impacts to California spotted owls.
5. Fuels reductions and forest management actions increase, with both positive and negative impacts on California spotted owls.
6. Barred owls increase in numbers and displace California spotted owls on the landscape.
7. Rodenticides increase on the landscape, impacting California spotted owl population survival rates.
8. Disease and parasites may increase on the landscape, impacting California spotted owl survival.
9. Development increases on the landscape, reducing California spotted owl habitat.
10. Recreation increases on the landscape, resulting in impacts to California spotted owl fecundity and occupancy.

Scenario 2: Factors that are currently having an influence on California spotted owl populations and analysis units continue at the current trajectory into the future, with implemented management efforts being fully successful. Under Scenario 2, we project the California spotted owl would have zero analysis units in stable condition, eight analysis units in declining condition and seven analysis units that are in strongly declining condition with the potential of extirpation in 40–50 years.

1. Large-scale high-severity fires increase slightly or remain stable due to management actions with the goal of maintaining high quality spotted owl habitat while reducing fuel loads on the landscape.

2. Tree mortality numbers remain stable or decrease slightly due to reduced fuel loads, providing larger trees with more resources to be more resilient to drought, disease, and beetles.
3. Drought conditions increase slightly into the future, resulting in both habitat impacts and physiological impacts to California spotted owls.
4. Effects of climate change increase slightly in the future, resulting in both habitat impacts and physiological impacts to California spotted owls.
5. Fuels reductions and forest management actions increase, with both positive and negative impacts on California spotted owls.
6. Barred owl management is effective in minimizing the risk of invasion.
7. Rodenticides remain stable on the landscape, with minor impacts to California spotted owl population survival rates.
8. Disease and parasites remain stable on the landscape, with minor impacts to the California spotted owl.
9. Development trajectories remain stable in potential California spotted owl habitat.
10. Recreation continues at the current rate within California spotted owl habitat with little to no impacts on California spotted owl occupancy or fecundity.

The outcome of future scenario 1 and future scenario 2 are very similar after 40–50 years. Under future scenario 1, where the intensity of the threats increases over time and management actions are not fully effective at addressing threats, the condition of almost all analysis units would decline. Overall, the resiliency of the Sierra Nevada would be very low under scenario 1 and because the condition of the coastal-southern California population would be extirpated, it would have no resiliency under scenario 1. Under future scenario 2, where the magnitude of the threats continues on the current trajectory and current management actions are fully effective in the future, the condition of analysis units and corresponding population resiliency decreases from current condition, although less than under future scenario 1. Under scenario 2, the Sierra Nevada population has very low resiliency, although closer to our scoring boundary of low resiliency, and the coastal-southern California population has very low resiliency. Scenario 2 would likely lead to reduced redundancy and representation for the species, but to a lesser extent than scenario 1, as the species would have less flexibility to adapt to changing environmental conditions. If the current conservation measures that are in place continue under scenario 2, there will be some protection for the species against certain ongoing threats compared to under scenario 1; however, even with these protections in place the species is still vulnerable to large-scale high-severity fire and climate change impacts.

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CHAPTER 1: INTRODUCTION

1.1 Petition History and Previous Federal Actions

The California spotted owl (*Strix occidentalis occidentalis*) is a subspecies of spotted owl that occurs throughout the Sierra Nevada mountains in California and Nevada (hereafter, referred to as Sierra Nevada), along the central California coast in the Coast and Transverse Ranges from Monterey County south into Ventura County (hereafter, referred to as coastal California), in southern California in the Transverse and Peninsular mountain ranges from Ventura County to San Diego County in the south (hereafter, referred to as southern California), and has been documented in the literature as occurring as far south as the Sierra Juarez and Sierra San Pedro Martir mountain ranges in Baja California Norte, Mexico (hereafter, referred to as Baja California). We, the U.S. Fish and Wildlife Service (Service), were petitioned to list the California spotted owl (CSO) as endangered or threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543) (Act), in December 2014 by the Wild Nature Institute and John Muir Project of Earth Island Institute and again in August 2015 by Sierra Forest Legacy and Defenders of Wildlife. In September 2015, the Service published a 90-day finding that the petition presented substantial scientific or commercial information indicating that listing CSO may be warranted (80 FR 56423, September 18, 2015). In November 2019, the Service published a 12-month finding in the Federal Register that listing CSO was not warranted (84 FR 60371, November 8, 2019). In August 2020, Sierra Forest Legacy, Defenders of Wildlife, and the Center for Biological Diversity filed a complaint challenging our 12-month finding that listing was not warranted. On November 30, 2021, the Service voluntarily remanded the not warranted finding and committed to a deadline of February 15, 2023, for submitting to the Federal Register a 12-month finding on CSO. Therefore, a review of the status of the subspecies was initiated to determine if listing is warranted. Based on the status review, the Service will issue a 12-month finding for CSO.

1.2 Methodology

This assessment draws scientific information from resources such as primary peer-reviewed literature, reports submitted to the Service and other public agencies, species occurrence information in Geographic Information Systems (GIS) databases, habitat information in GIS databases, and expert experience and observations. It is preceded by and draws upon analyses presented in other Service documents, including the 90-day finding (80 FR 56423) and the remanded 12-month finding (84 FR 60371). Finally, we coordinated closely with our partners engaged in ongoing research and conservation efforts in state and federal agencies as well as private and non-governmental organizations. This assures consideration of the best scientific and commercial data available.

Analytical Framework

This Species Status Assessment (SSA) Report, developed using the SSA framework (Service 2016a, entire), provides an in-depth review of the species' biology and influencing factors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability (see Figure 1). This SSA Report, which provides our assessment of the species status, can subsequently be updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to

Consultations to Recovery. As such, this SSA Report will be a living document upon which other documents, such as listing rules, recovery plans, and 5-year reviews, would be based if the species warrants listing under the Act.

This SSA Report for CSO is intended to provide the biological support for the decision on whether to recommend listing the subspecies as threatened or endangered and, if so, also for determining which areas may meet the definition of critical habitat. Importantly, the SSA Report does not include a recommendation or determination by the Service on whether CSO should be proposed for listing as a threatened or endangered species under the Act. Instead, this SSA Report provides a review of the available information strictly related to the biological status of CSO. The decision whether to list CSO will be made by the Service after reviewing this document and all relevant laws, regulations, and policies.

This SSA Report characterizes the species' ability to sustain populations in the wild over time (viability) based on the best scientific understanding of current and future abundance and distribution within the species' ecological settings. To do so, we use the SSA Framework (Service 2016a) and the conservation biology principles of resiliency, redundancy, and representation as a lens to evaluate the current and future condition of the species. We assessed future condition of the species over a time frame of 40–50 years because this range of time represents our best professional judgment of the projected future conditions related to climate change for California, CSO generation time, and regeneration time of large trees.

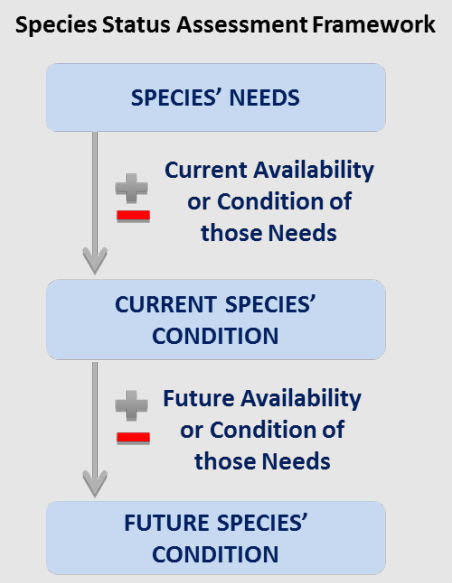


Figure 1: Species Status Assessment Framework.

Resiliency is the ability of a species to withstand stochastic events, the normal year-to-year variations in both environmental conditions (i.e., temperature, rainfall, and periodic disturbances such as fires, floods, and storms), and demographic conditions (i.e., mortality, fecundity) (Redford et al. 2011, p. 40). Determined by the size and growth rate of the populations comprising the species, resiliency can be evaluated to gauge the ability of a species to withstand the natural range of favorable and unfavorable conditions. For CSO, we evaluate resiliency by assessing CSO's

demographic factors of dispersal, survival, fecundity, occupancy, and population growth, and habitat elements of canopy cover and large trees.

Redundancy is the ability of a species to withstand catastrophic events, i.e., natural or anthropogenic stochastic events that would result in the loss of a substantial component of the overall population. Characterization of a species' redundancy takes into consideration both an assessment of the size and distribution of its population(s), and an evaluation of the kinds and likelihood of reasonably plausible catastrophic events to which the species could be exposed. For CSO, we measure redundancy by assessing the number and distribution of populations across the subspecies' range in relation to the scale of catastrophic events that are likely to occur, such as high severity fire, extreme drought, excessive precipitation, or prolonged and persistent competition and displacement due to barred owl expansion.

Representation is the ability of a species to withstand and adapt to long-term changes in environmental conditions (i.e., significant changes outside the range of normal year-to-year variations). The measure of a species' representation may be determined by the breadth of genetic and environmental diversity within and among populations. For CSO, we measure representation by assessing genetic diversity and unique ecological settings across the subspecies' range. For areas where we do not have genetic information, we rely on the extent and variability of habitat and climate characteristics to evaluate representation.

To evaluate the biological status of CSO both currently and into the future, we assessed a range of conditions to allow us to consider the species' resiliency, redundancy, and representation (together, the 3 Rs). This SSA Report provides a thorough assessment of the CSO's biology and natural history and assesses demographic risks and influencing factors (both negative and positive) in the context of determining the species viability and risk of extinction.

The format for this SSA Report includes: a description of CSO, its life history, and habitat (Chapter 2); the habitat and demographic needs of individuals, populations, and the species overall (Chapter 3); a review of the influencing factors that affect the species viability and to what degree (Chapter 4); an analysis of CSO's current condition and a framework for determining population resiliency (Chapter 5); an analysis of the species future condition under three plausible future scenarios (Chapter 6); and a conclusion that describes the viability of CSO in terms of resiliency, representation, and redundancy (Chapter 7). This document is a compilation of the best available scientific and commercial information and a description of the past, present, and likely future risk factors to CSO.

CHAPTER 2: SPECIES BACKGROUND

2.1 Species Description and Taxonomy

California spotted owls are medium-sized brown owls measuring 46.6–48.3 centimeters (cm) (18.3–19.0 inches (in)) with a mottled appearance, round face, large pale brown facial disks, dark brown eyes, and a yellowish green bill (Verner et al. 1992, p. 55; Gutiérrez et al. 2020), "Appearance" section). Females are generally slightly larger than males (Verner et al. 1992, p. 55). The mass of males is approximately 470–685 grams (g) (16.6–24.2 ounces (oz)), whereas the mass of

females is approximately 535–775 g (18.9–27.3 oz) (Gutiérrez et al. 2020, "Appearance" section). The spotted owl was first described by John Xanthus in 1859 as *Syrnium occidentale* based on a specimen collected at Fort Tejon, Kern County, California (Xantus 1859, pp. 189–190). The species was later reassigned to the genus *Strix* (Ridgway 1914, pp. 648–650).

The American Ornithological Society currently recognizes three distinct subspecies of spotted owls: northern spotted owl (*Strix occidentalis caurina*), California spotted owl (*Strix occidentalis occidentalis*), and Mexican spotted owl (*Strix occidentalis lucida*) (AOU 1957). Subspecies of spotted owls have historically been distinguished based on body size, plumage, and range. More recently, there have also been genetic studies including all three subspecies. We have no information to suggest there is scientific disagreement about the California spotted owl's taxonomy.

Given similarities between the subspecies of spotted owls, this SSA Report uses available relevant literature for both the northern spotted owl and the Mexican spotted owl as necessary and appropriate. The term CSO is used when talking only about the California spotted owl subspecies. Spotted owl is used when talking about the species as a whole. We clearly identify when northern spotted owl or Mexican spotted owl is referred to in this SSA Report.

2.2 Genetics

Genetic studies have been useful in reinforcing subspecific identification between spotted owl subspecies, including studies using mitochondrial DNA (Barrowclough et al. 1999, 2005; Haig et al. 2004; Miller et al. 2017), microsatellite loci (Funk et al. 2008; Miller et al. 2017), and whole-genome assemblages (Hanna et al. 2018; Fujito et al. 2021). Phylogenetic analyses of the mitochondrial haplotypes (specific regions of mitochondrial DNA that cluster together to show phylogenetic origins) confirmed significant differences between northern spotted owls and the other spotted owl subspecies (Haig et al. 2004, pp. 688–690). Although Haig et al. (2004) found weaker support distinguishing between CSO and Mexican spotted owls, their study found CSO and Mexican spotted owl did further segregate into separate California and Mexican clades. In another study, most variation of mitochondrial DNA was distributed at the level of three subspecies (i.e., northern spotted owl, CSO, and Mexican spotted owl) (Barrowclough et al. 1999, pp. 922–923). Integrating microsatellite loci with previous mitochondrial DNA studies also supported recognition of the three subspecies (Funk et al. 2008, pp. 165–166). Species-specific principal component analyses using a spotted owl genome assembly showed clear separation between northern spotted owl and CSO samples, but the study did not include Mexican spotted owl samples (Fujito et al. 2021, pp. 3–4).

There is some overlap in range between northern spotted owl and CSO, and interbreeding between the two subspecies occasionally occurs (Haig et al. 2004, p. 690; Barrowclough et al. 2011, pp. 581, 583–586; Miller et al. 2017, pp. 6871, 6875–6877; Hanna et al. 2018, pp. 3947–3948, 3950–3951). Genetic studies support existence of a hybrid zone in north central California (Haig et al. 2004, pp. 688–690; Barrowclough et al. 2005, pp. 1111–1113; Miller et al. 2017). Gene flow between spotted owl subspecies indicates bidirectional introgression between northern spotted owl and CSO; that is, both subspecies are mating with each other when dispersing through their respective ranges (Barrowclough et al. 2005, pp. 1113–1114, 2011; Funk et al. 2008, pp. 165–166). Results from

analysis of microsatellite loci indicate that both hybridization and long-distance migration occur between spotted owl subspecies (Funk et al. 2008, p. 167).

California spotted owls have the lowest genetic diversity among the subspecies compared to northern and Mexican spotted owls, suggesting CSO is of more recent origin than the other spotted owl subspecies or the CSO population is much smaller than the northern and Mexican spotted owl populations (Barrowclough et al. 1999, pp. 919, 927; Haig et al. 2004, p. 683). Within CSO, genetic differences between CSO found in the Sierra Nevada and CSO found in mountain ranges throughout southern California suggest limited interbreeding between these two areas (Barrowclough et al. 2005, pp. 1113–1114; Hanna et al. 2018, pp. 3947–3948, 3950). However, these genetic studies are limited by sample size and sampling locations. We are only aware of one study that includes CSO from coastal California; Barrowclough et al. (2005, p. 1114) shows gene flow between geographically adjacent spotted owl samples, with some evidence of asymmetrical gene flow between CSO in Carmel, California (coastal California), and the Sierra Nevada.

Genetic studies have also looked at hybridization with invasive barred owls (*Strix varia*). Spotted owl and barred owl species cluster separately from each other in genetic analyses, with hybrids scattered between the two species clusters (Fujito et al. 2021, pp. 3–4). See Chapter 4.6 Competition and Hybridization with Barred Owls for more information about CSO hybridization with barred owls.

2.3 Geographic Distribution

California spotted owls are distributed across habitat in California and Nevada including the Sierra Nevada, coastal California, and southern California. The California spotted owl has also been documented in the Sierra San Pedro Martir mountains in Baja California Norte, Mexico, with a few scattered records of the spotted owl in Baja California between 1887 and 1972 (Grinnell 1928, p. 242; Wilbur 1987, p. 170), and early ornithological references described the spotted owl's range as Lower California, which can be interpreted as Baja California (AOU 1886, p. 199; Ridgway 1887, p. 259). However, there is some disagreement in the literature over how to interpret these early accounts. Some view these records as valid documentation of the species occurring in Baja California in the past and that the current lack of records suggests the species is now extirpated from this area (Howell et al. 2001, p. 27; Erickson et al. 2013, p. 605), whereas others consider that they represent uncommon or rare occurrences of the species outside of their range (Wilbur 1987, p. 170). In addition, an early 20th century ornithologist questioned the status of the species in Baja California and noted there were no specimens or records of the species from the area in the U.S. National Museum (Grinnell 1928, p. 242), and many researchers now question whether the species ever actually occurred in Baja California (Erickson in litt. 2022; Unitt in litt. 2022). However, other anecdotal accounts over the last 20 years (approximately 2005 through 2019) report periodically seeing or hearing spotted owls. In some instances, these occurrences were during the fall and winter season after a good year of summer rains in Sierra San Pedro Martir National Park (Bowers pers. comm. 2022; Porras-Peña in litt. 2022; De Leon Giron in litt. 2022). There are only a few accounts of the species with none of those accounts mentioning breeding or evidence of breeding pairs. Therefore, we consider CSO only a rare visitor of Mexico, and do not consider Baja California as its own population. It is possible this population was historically connected with southern California, as

the Sierra San Pedro Martir and Sierra Juarez are southern extensions of the Peninsular Ranges that include CSO in southern California (Gutiérrez et al. 2017, p. 240). Dispersal patterns among the sky islands of forest in Mexico and southern California may be more similar to the Mexican spotted owl that disperses across unsuitable habitat (see 3.2.3.1 Natal Dispersal), but we have no evidence to determine what the level of connectivity is today. Given the uncertainty surrounding CSO observations/occurrences in Baja, and lack of information on its habitat or breeding status, we will not be addressing the status of CSO in Baja in this SSA Report. We acknowledge that an earlier version of the CSO SSA Report included Baja California as its own population (Service 2019), but we have changed our approach based on new information available to us, as described above. Figure 2 represents our understanding of the current range of CSO, with Baja California also identified in this instance (based on Gutiérrez et al. 2017 and other CSO occurrence information). The term "range" used throughout the SSA Report refers to the CSO range only within the limits of California and Nevada.

California spotted owls are continuously distributed throughout the forests of the western side of the Sierra Nevada from Shasta County south to the Tehachapi Pass in Kern County (Gutiérrez et al. 2017, pp. 13–14). They are sparsely distributed on the eastern side of the Sierra Nevada into western Nevada (GBBO 2012, p. Spp-47-4). Outside of the Sierra Nevada, the species range is not contiguous. Along the California coast and into southern California, the species is found in the Coast, Transverse, and Peninsular mountain ranges from Monterey County in the north to San Diego County in the south (Gutiérrez et al. 2020, "Distribution" section). However, there is a large gap in the species range around San Luis Obispo County where the species is not known to occur (see Figure 2). The Tehachapi Pass between the Sierra Nevada to the east and the Transverse Range to the west is a significant gap between CSO in the Sierra Nevada and CSO in coastal and southern California (Verner et al. 1992, p. 4). California spotted owls are absent from the Santa Cruz Mountains (part of the Coast Range) in California, where suitable habitat appears to be present (Gutiérrez et al. 2017, p. 240).

California spotted owls are currently found throughout their known historical range, although there is evidence of a decrease in abundance in parts of the range including both the Sierra Nevada and southern California (Franklin et al. 2004, pp. 23–42; Tempel et al. 2014b, pp. 90–94, 2022, p. 18; Conner et al. 2016, pp. 7–18; Hanna et al. 2018, pp. 3947–3949) (see Chapter 5: Current Condition for more information about abundance). The majority of CSO are found in mid-elevation, mixed-conifer forest on the west slope of the Sierra Nevada (Gutiérrez et al. 2017, p. xviii). California spotted owl nest trees were found from 305 meters (m) (1,000 feet (ft)) to 2,340 m (7,740 ft) in elevation in the Sierra Nevada and between 1,000 m (3,281 ft) and 2,560 m (8,400 ft) in the Los Padres National Forest and San Bernardino Mountains in southern California (Verner et al. 1992, p. 60).

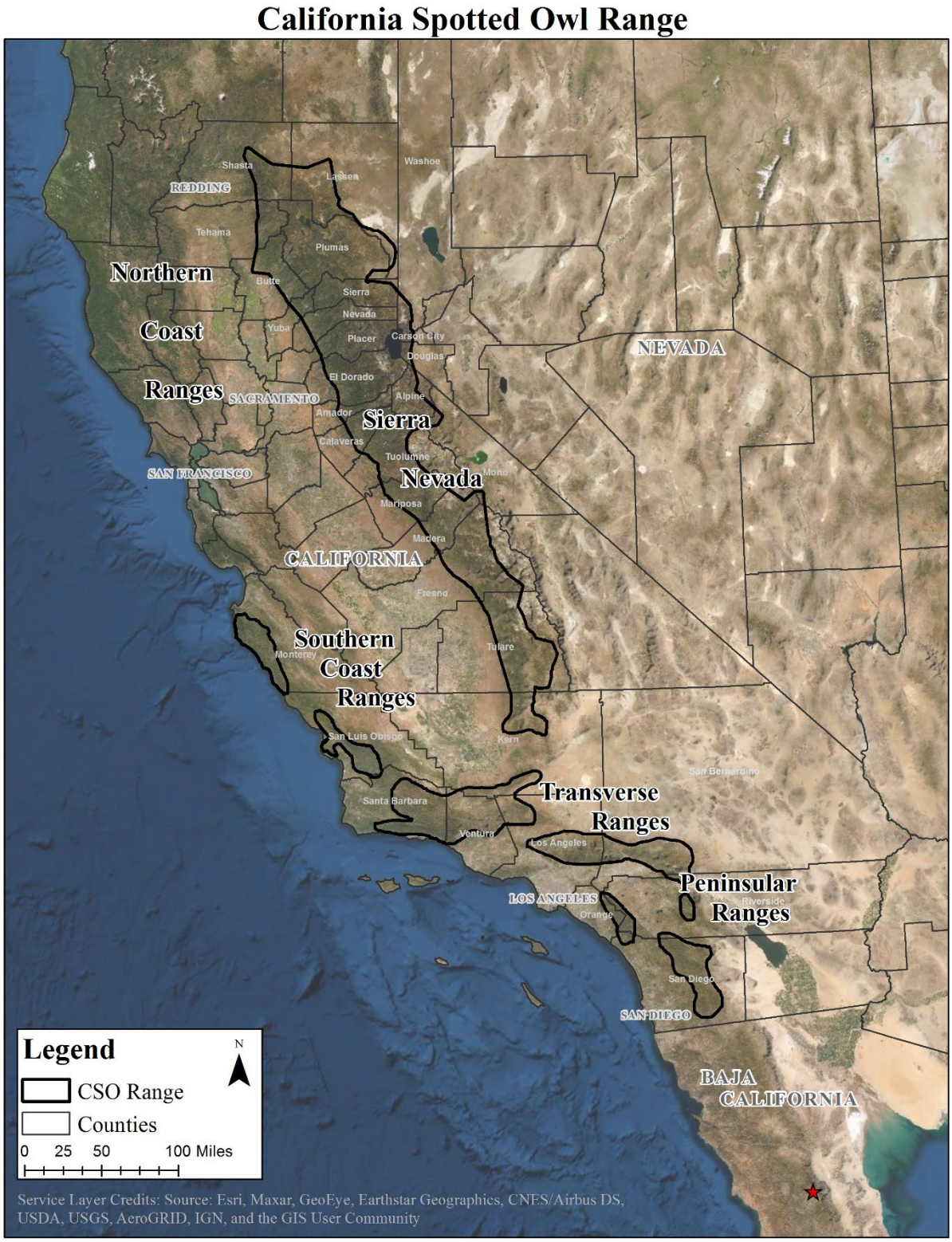


Figure 2: California spotted owl range map. Maps were developed with occurrence data from U.S. Forest Service, California Department of Fish and Wildlife, Nevada Department of Wildlife, and eBird. The red star indicates the approximate location of CSO occurrences in Baja California and was extracted from Gutiérrez et al. 2017 (p. 13). This will be the only map with Baja California, Mexico, identified as part of the CSO range.

2.4 Life History

California spotted owls are long-lived (approximately 16–23 years) with high adult survival and low reproductive output (Seamans and Gutiérrez 2007a, p. 57; Gutiérrez et al. 2020) Demography and Populations" section). California spotted owls form monogamous pair bonds, although occasionally bonds may break and new bonds may form due to circumstances such as the death of a mate or low reproductive output with a previous mate (Blakesley et al. 2006, p. 74; Gutiérrez et al. 2011, p. 592, 2020) "Behavior" section). Pairs will defend a territory from neighboring pairs and vagrant CSO, and they exhibit high territory fidelity (Gutiérrez et al. 2020, "Sounds and Vocal Behavior" and "Behavior" sections). Passively recorded audio data suggests that CSO use active territorial defense (i.e., through vocalizations) close to sunset and at the edges of territories, where habitat is generally lower-quality than preferred foraging sites, roost sites, and core territory areas (Wood et al. 2019b, pp. 232, 236–239). Territories—the area actively defended by a breeding pair—can overlap with neighboring pairs and are smaller than home ranges (Gutiérrez et al. 2017, pp. xvi, 294). Estimates of territory size have varied from 203 ha (502 ac) to 813 ha (2,009 ac) with higher estimates in the northern Sierra Nevada and lower estimates in southern California (Bingham and Noon 1997, p. 136; Blakesley et al. 2005, p. 1556; Seamans and Gutiérrez 2007b, p. 568; Tempel et al. 2014a, p. 2091). Higher quality territories measured in adult survival, territory colonization, and territory extinction, tend to have a greater proportion of higher canopy cover (≥70%) (Tempel et al. 2014a, p. 2089; Gutiérrez et al. 2017, pp. 271–273). Home ranges, or areas used by a pair to meet requirements for survival and reproduction, are about 400–1,200 hectares (ha) (1,000–3,000 acres (ac)) in size (Gutiérrez et al. 2017, p. xviii). Home ranges are typically larger in the northern portion of the range (>1,000 ha (2,470 ac)) and smaller in the southern portion of the range (<1,000 ha (2,470 ac)) due to differences in selected prey species (Gutiérrez et al. 2017, p. xviii). Male and female home range size for CSO were not statistically different in a study looking at habitat use in a burned landscape (Eyes et al. 2017, p. 381). However, female CSO home ranges were twice the size of male home ranges in unburned forest, with nonbreeding females having the largest home range sizes (Blakey et al. 2019, pp. 917, 919).

Breeding season begins in mid-February and the juvenile dependency period can last through mid-September; nesting generally starts earlier at lower elevations (Gutiérrez et al. 2017, p. 53; Gutiérrez et al. 2020, "Breeding" section). During the breeding season, CSO tend to spend the majority of their time at activity centers of around 121 ha (299 ac) (Verner et al. 1992, p. 87; Berigan et al. 2012, p. 299). Activity centers are the area where CSO spend most of their time in which they nest, roost, and forage (Verner et al. 1992, p. 87; Gutiérrez et al. 2017, pp. 270–271). In the Sierra Nevada, a majority of CSO used more than one nest/roost area over the three-year study period (2015 –2017; 86% of 36 GPS-marked CSO, range 2–6) (Berigan et al. 2019, p. 474). Spotted owls typically have only one nest per breeding season and they rarely re-nest if the first nests fails (Gutiérrez et al. 2020, "Breeding" section), although there is some evidence that northern spotted owls may nest more than once per season if their initial nesting attempt fails (Sovern et al. 2011, p. 103). Peak egg laying occurs in mid-April (Verner et al. 1992, p. 62). Females typically lay 1–3 eggs, with survival of offspring into adulthood highest when two young fledge in comparison to singletons and triplets (Peery and Gutierrez 2013, p. 132; Gutiérrez et al. 2020, "Demography and Populations" section). Incubation in northern spotted owls lasts for 30 ± 2 days (Forsman et al. 1984, p. 33) and is likely similar for CSO. Male spotted owls provide food and protection for the

female while the female incubates and broods the nest (Gutiérrez et al. 2020, "Breeding" section). After hatching, owlets are covered in natal down for about 10 days, which then starts to be replaced by juvenile plumage (Gutiérrez et al. 2020, "Breeding" section). Hatchlings rely on both parents for protection and food (Gutiérrez et al. 2020, "Breeding" section). Juvenile northern spotted owls fledge approximately 35 days after hatching (Forsman et al. 1984, p. 33), and time to fledging is presumed to be similar for CSO. Juveniles will leave the nest and climb in nearby trees before they can fly, relying on multi-layered forest structure to move among trees and about the forest floor (Whitmore 2009, pp. 4–5). After fledging, juveniles rely on parents for food and protection, although parental care will progressively decrease over time (Gutiérrez et al. 2020, "Breeding" section). In northern spotted owls, parental care usually ends in late August or September, and is likely similar for CSO (Forsman et al. 1984, p. 5). Although difficult to estimate due to dispersal, juvenile survival in CSO is low: approximately 0.368 for CSO in the San Bernardino Mountains in southern California (LaHaye et al. 2004, p. 1056), and 0.333 for CSO in the northern portion of the Sierra Nevada (Blakesley et al. 2001, p. 667). Juvenile spotted owls are particularly vulnerable during the fledging and early dispersal stages, with a high mortality rate due to predation, starvation, and accidents (e.g., falling from a tree) (Gutiérrez and Carey 1985, pp. 41, 63). No information is available regarding juvenile survival for CSO in other portions of the species' range.

Spotted owls have obligate juvenile dispersal, meaning they always disperse from their natal areas in the year they hatch. Natal dispersal occurs during the fall, after juveniles have reached adult weight and parental care stops (Gutiérrez et al. 2020, "Breeding" section). Studies of juvenile dispersal of CSO in southern California, based on recaptures of banded birds, found that average juvenile dispersal was 9.7–11.3 kilometers (km) (6–7 miles (mi)), and ranged from 3.2–37.0 km (2–23 mi) (LaHaye et al. 2001, p. 691). In the San Bernardino Mountains, females dispersed slightly farther than males, although this result was not statistically significant (Gutiérrez et al. 2017, p. 250). In northern spotted owls, females generally disperse farther than males (Forsman et al. 2002, p. 15; Miller et al. 2018, p. 830). Larger dispersal distances, up to 177 km (110 mi), have been documented in both northern and Mexican subspecies (Gutiérrez and Carey 1985, p. 60; Ganey et al. 1998, p. 206; Hollenbeck et al. 2018, p. 533). California spotted owl sub-adults are non-territorial and considered "floaters" until they occupy a territory (LaHaye et al. 2001, p. 696; Gutiérrez et al. 2017, p. 16). Sub-adults in southern California typically acquire territories after 1–3 years, with most individuals settling in areas that had been previously occupied by CSO (LaHaye et al. 2001, p. 696). Adult CSO typically do not shift territories or undergo breeding dispersal from an established territory (Blakesley et al. 2006, p. 76; Zimmerman et al. 2007, p. 963; Gutiérrez et al. 2011, p. 592); however, some breeding dispersal occurs in adults or pairs that have been unsuccessful in mating or if habitat is altered (Blakesley et al. 2006, p. 71).

Breeding only occurs once a pair is formed and settled into a territory (Gutiérrez et al. 2017, p. 15). Pairs can breed in consecutive years, but in certain conditions may use a "bet hedging" reproductive strategy in which they postpone reproduction until temporarily poor environmental conditions improve ((Stearns 1976, pp. 4, 15–26; Franklin et al. 2000, p. 539; Gutiérrez et al. 2017, p. xvi). The number of young fledged annually per territorial female CSO in several areas within the Sierra Nevada ranged from 0.478–0.988 (Blakesley et al. 2010, pp. 1, 18). The number of offspring a

female produced annually was higher in adult females than first and second year sub-adult females (LaHaye et al. 2004, p. 1056; Blakesley et al. 2010, p. 1). Figure 3 summarizes the life history of CSO.

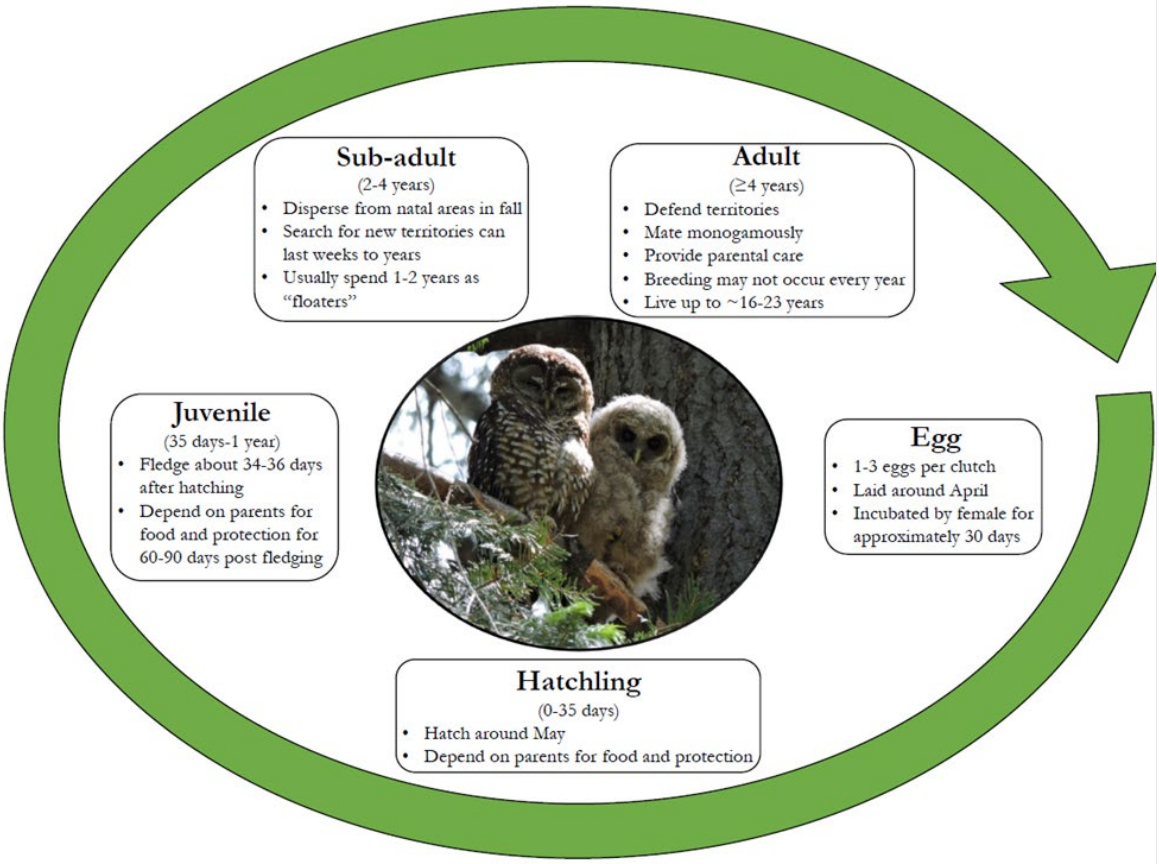


Figure 3: California spotted owl life history diagram. Photo of adult and young California spotted owl, Carson Range, Nevada provided by Mark Enders, Nevada Department of Wildlife.

2.5 Habitat

In general, CSO nest in areas of mature, multistoried forests with complex structure, larger trees, multi-layered high canopy cover, and large amounts of coarse woody debris , while areas with higher heterogeneity of forest types and the edges between them are important for foraging (Gutiérrez et al. 2017, p. xvii). These habitat components provide structure and characteristics required for nesting, roosting, and foraging. Coarse woody debris for the purpose of this SSA Report refers to fallen dead trees and the remains of large branches on the ground. Coarse woody debris in areas of multi-layered high canopy cover is conducive for fungal growth, a food source for many CSO prey species (Verner et al. 1992, pp. 71–72; Pyare and Longland 2002, pp. 1016–1017).

In the Sierra Nevada, a majority of CSO occur within mid-elevation ponderosa pine (*Pinus ponderosa*), mixed-conifer, white fir (*Abies concolor*), and mixed-evergreen forest types, with few occurring in the lower elevation oak woodlands of the western foothills (Gutiérrez et al. 2017, p. 109). It is important to note that most of the available literature on habitat for the Sierra Nevada is focused on the westside of the mountain range and does not include habitat characteristics from the

eastside, where habitat is more open and less dense compared to the westside. In coastal and southern California, CSO are found in riparian/hardwood forests and woodlands, live oak/big cone fir forests, and redwood/California laurel forests (Gutiérrez et al. 2017, p. xxvi). Further information on these habitat types can be found at California Wildlife Habitat Relationship (https://wildlife.ca.gov/Data/CWHR/Wildlife-Habitats). In southern California, vegetation types differ relative to the Sierra Nevada and what is considered a large tree in southern California may not be comparable to what is considered a large tree in the Sierra Nevada (see section 2.5.1 Nesting Habitat). However, CSO in southern California still select for territories containing larger trees (LaHaye et al. 1997, pp. 42, 47) and predominantly closed canopy cover (Smith et al. 2002, pp. 137, 142, 144).

2.5.1 Nesting Habitat

California spotted owls can use a variety of habitat types for nesting. At higher elevations, the species primarily uses conifers for nesting, and as elevations decrease, they increasingly use hardwoods (Gutiérrez et al. 2020, "Habitat" section). Important components of nesting habitat include high canopy cover, larger trees, and high habitat heterogeneity. High canopy cover is an important predictor for CSO nest locations (North et al. 2017, pp. 166, 172–175) and multi-layered high canopy cover around the nest tree and in territories is an important factor associated with CSO reproductive success (Hunsaker et al. 2002, pp. 693–699; Blakesley et al. 2005, pp. 1554, 1558–1562). A nest area with canopy cover of greater than 70% is associated with higher site occupancy, and occupancy sharply declines in habitat with less than 40% canopy cover (Blakesley et al. 2005, p. 1559; Seamans 2005, pp. iii, 90, 100; Seamans and Gutiérrez 2007b, pp. 566, 568; Tempel et al. 2014a, pp. 2089, 2091, 2016, pp. 747, 759). After substantial changes in the landscape due to drought and a megafire in Yosemite National Park (i.e., the 2013 Rim Fire), habitat selection analysis found that CSO still selected territories with higher canopy cover relative to what is available. California spotted owls selected areas with at least 40% canopy cover in burned forest and areas with 48% canopy cover in unburned forest (Schofield et al. 2020, pp. 3, 5). In the same study, an equal number of CSO were found nesting in burned and unburned forest (Schofield et al. 2020, pp. 3, 5), although CSO avoided areas with more than 30% high severity fire (Schofield et al. 2020, p. 5). Gaps and small openings of canopy cover are important components of foraging habitat (see Section 2.5.2), but there are generally no gaps around the nest stand (North et al. 2017, p. 166). Even in southern California where the habitat is naturally more fragmented with less canopy cover available, CSO still select for nest areas with higher canopy cover relative to what is available (Smith et al. 2002, pp. 142–143).

California spotted owls use a subset of larger trees or snags as their nest trees, with the average nest tree measuring 124 cm (49 in) diameter at breast height (dbh) and 31 m (103 ft) tall in the Sierra Nevada (Gutiérrez et al. 2017, p. 50). In addition to nest tree size variation according to nest type, nests also vary between hardwood and conifer species, with the typical hardwood nest tree greater than 76.2 cm (30 in) dbh and 16.8 m (55 ft) tall (Verner et al. 1992, p. 92). The nest tree itself is critical for CSO reproductive success because it provides the space and structure needed for nests and fledglings, along with protection from predators and inclement weather. California spotted owls do not build their own nest but rely on larger trees that provide multi-layered high canopy cover with open cavities (created because of fallen branches, woodpeckers, etc.), broken tops, platforms,

and old raptor nests (Gutiérrez et al. 2020, "Habitat" and "Breeding" sections). The nest tree chosen within a territory is typically one of the oldest and largest live or dead trees within the nesting territory with many defects like cracks, disease scars, or decaying wood (Verner et al. 1992, pp. 6, 60, 71; North et al. 2000, p. 797). The average age of nest trees in the southern Sierra Nevada was found to be >227 years (North et al. 2000, p. 802). In southern California, CSO use cavity, broken-top, and platform nests with different characteristics - cavity nest trees are 108.3 cm (42.6 in) dbh, broken-top nest trees 122.3 cm (48.1 in) dbh, and platform nests are typically smaller with overall combined nest trees measuring 90.8 cm (35.7 in) dbh and 24.4 m (80.1 ft) tall when all nest types, including platform nests, were considered (LaHaye et al. 1997, pp. 42, 47; Gutiérrez et al. 2017, p. 50; Tanner 2022, pers. comm.). In southern California CSO use of platform or old raptor nests is more common; thus, owls with these types of nests were observed using trees as small as 33 cm dbh (13 in; Tanner 2022, pers. comm.) with mean values of 75.0 cm (29.5 in) dbh (LaHaye et al. 1997, p. 45).Within their nesting territory, CSO select for nest sites farther away from the forest edge (Phillips et al. 2010, p. 312). California spotted owl nest trees with higher reproductive output, measured by number of young fledged per territory, tend to be used repeatedly, whereas nest trees with low reproductive output are usually only used once (North et al. 2002, pp. 118–119).

California spotted owl occupancy, colonization, adult survival, and reproductive success are all positively associated with an increasing amount of structurally complex (i.e. multistoried) habitat on the landscape (Franklin et al. 2000, p. 578; Blakesley et al. 2005, p. 1562; Tempel et al. 2014a, pp. 2103–2104). The biological and physical components that create habitat heterogeneity and complex structure are areas of multi-layered high canopy cover, large trees, coarse woody debris, understory and mid-story vegetation, patches of burned habitat, riparian habitat, large diameter standing dead trees (snags), and areas with small openings of canopy cover within a home range. As discussed above, CSO select for habitat with multi-layered high canopy cover and large trees especially for nesting; however, there are a variety of other habitats within a heterogeneous landscape that CSO use and which may provide specific resources, such as prey.

2.5.2 Foraging Habitat and Prey

California spotted owls can also use a variety of habitats to forage. California spotted owls primarily prey upon a variety of small to medium sized mammals, including but not limited to flying squirrels, woodrats, and pocket gophers, as well as birds, lizards, and insects (Gutiérrez et al. 2017, p. 28). Diet varies across the species' range and habitat types and following wildfires. In the Sierra Nevada, above approximately 1,200 m (3,937 ft) in coniferous forests, CSO most commonly consume Humboldt's flying squirrels (*Glaucomys oregonensis*) (Laymon 1988, pp. 130–154; Verner et al. 1992, pp. 4, 65–69; Munton et al. 2002, pp. 99, 101–104). Northern flying squirrels are primarily found in coniferous and mixed forest but can also be found in deciduous woods and riparian woods (Cassola 2016a, p. 3). Humboldt's flying squirrels in the range of the CSO were previously classified as northern flying squirrels (*Glaucomys sabrinus*) (Arbogast et al. 2017, p. 1027). Preferred habitat conditions of northern flying squirrels include cool, moist, mature forest with abundant standing and down snags where they can forage on mostly fungi and lichens (Cassola 2016a, p. 3). In lower elevation oak woodlands and riparian-deciduous forests in the Sierra Nevada and southern California, CSO select for woodrats, including both dusky-footed and big-eared (*Neotoma* spp.) (Verner et al. 1992, pp. 4, 65, 68–69; Smith et al. 1999, pp. 22, 24–28; Munton et al. 2002, pp. 99,

101–104). Due to this elevational gradient in prey distribution, CSO select foraging sites characteristic of flying squirrel habitats at higher elevations and woodrat habitats at lower elevations (Kramer et al. 2021b, pp. 12–14). Both the dusky-footed and big-eared woodrats are found in densely wooded areas with heavy undergrowth including chaparral, riparian woodlands, hardwood forests, conifer forests, and mixed forests. The woodrat diet includes seeds, nuts, acorns, fruits, green vegetation, inner bark, and fungi (Cassola 2016b, p. 3; Álvarez-Castañeda and Lacher 2016, p. 3). In the Sierra National Forest, a multi-year diet study found pocket gophers (*Thomomys* spp.) were the second most common prey species of CSO in both lower and upper elevation vegetation types (Munton et al. 2002, p. 99) following northern flying squirrels or woodrats. Pocket gophers are found in a wide variety of habitats from desert scrub to high elevation coniferous forests in open areas with deep soil (Lacher et al. 2016, p. 3). Pocket gophers primarily eat roots, bulbs, tubers, and occasionally above-ground plant parts (Greene 1999, p. 4).

California spotted owls will also eat mice, voles, birds, lizards, and insects (Laymon 1988, pp. 130–154; Verner et al. 1992, pp. 65, 68–69; Smith et al. 1999, p. 24; Munton et al. 2002, pp. 101–104). California spotted owls have low metabolic rates requiring the caloric equivalent of consuming a flying squirrel every 1.8 days or a woodrat every 3.7 days (Weathers et al. 2001, p. 687). Some individuals have smaller home ranges where woodrats are the primary prey source, presumably because woodrats have a higher caloric gain per successful foraging event and are found in higher densities than northern flying squirrels (Zabel et al. 1995, pp. 433, 435–438).

There is some evidence that CSO diet may shift following wildfires. In national parks in the Sierra Nevada that have implemented longstanding fire management efforts (i.e., prescribed fire and managed wildfire), the CSO diet contains a higher proportion of woodrats and pocket gophers relative to flying squirrels (Hobart et al. 2021, pp. 254, 256). However, in areas with frequent and extensive wildfires, CSO consumed proportionally more flying squirrels although woodrats and pocket gophers still contributed more to the overall diet (Hobart et al. 2021, p. 256). Interestingly, these results did not support the authors' hypothesis that wildfires would shift diet away from flying squirrels since flying squirrels are associated with closed-canopy forests and these forests are more likely to be impacted by wildfire (Hobart et al. 2021, p. 254). Other studies have found pocket gophers are an important prey species following wildfires in the Sierra Nevada (Bond et al. 2013, p. 114).

California spotted owls tend to forage in larger trees (see 3.1.2 Large Trees), likely due to the canopy cover provided by larger trees and the important resources such as shelter and food that larger trees provide for prey species (Laymon 1988, pp. 47, 71, 77, 100; Verner et al. 1992, pp. 9–10, 60, 88; Moen and Gutierrez 1997, pp. 1281, 1284). However, CSO have also been documented utilizing medium size trees (defined by the authors as >25 cm dbh (9 in)) for foraging while avoiding areas dominated by small trees (<25 cm dbh (9 in)) (Kramer et al. 2021a, pp. 4, 6). Coarse woody debris is also an important habitat feature for CSO because it provides food, shelter, and protection for prey species, especially woodrats (Waters and Zabel 1995, pp. 861–862; Pyare and Longland 2002, pp. 1016–1017; Innes et al. 2007, pp. 1523, 1526; Kelt et al. 2013, p. 1208). Recent research shows that CSO were more successful at capturing prey in territories with taller multilayered forests, higher vegetation heterogeneity, and near forest edges (Zulla et al. 2022, pp. 7–8); CSO also had higher reproductive success in territories with higher mean canopy cover, taller trees, and more

shrubby vegetation (Wilkinson et al. in prep., p. 2). However, riparian areas within forested landscapes that provide heterogeneity and increased foraging habitat may not always exhibit high canopy cover and large trees (Meyer et al. 2005, p. 275; Irwin et al. 2007, p. 1189; Bond et al. 2016, p. 1290). Heterogeneous forests, such as those found on private lands, may provide more habitat for CSO than was previously understood (Atuo et al. 2019, p. 295), as some privately-owned study areas have higher numbers of CSO occupied sites than adjacent Forest Service study areas (Roberts et al. 2017, p. 113).

2.5.3 Roosting Habitat

California spotted owl roosting habitat is very similar to nesting habitat. The species can roost in a variety of habitat types, including those habitat types described above for nesting habitat. Specific components of roosting habitat include multi-layered high canopy cover and presence of large trees. As they learn to fly, recently fledged CSO are often found roosting close to the nest tree in multi-layered forest with high canopy cover (Whitmore 2009, pp. 31–33). It is believed that such forests provide the young CSO with protection from predators and from high temperatures. California spotted owls have been found to have a low heat tolerance in comparison to other bird species, beginning to show heat stress at 30–34º Celsius (86–93º Fahrenheit). The cooler microclimates that multi-layered high canopy cover provides are important for both juveniles and adults during warm summers (Weathers 1981, pp. 358–359; Barrows 1981, pp. 303–305; Weathers et al. 2001, pp. 678–679). Behavioral studies show that CSO have an adaptive capacity to roost in cooler microclimates (promoted by higher elevations, taller canopy height, and greater canopy cover), especially in forest stands that are on warmer slopes (McGinn et al. in review, p. 2). Presence of large trees is also important for CSO roosting, as individuals tend to roost in large trees, likely due to the canopy cover provided by large trees and the resources they provide for prey species (Laymon 1988, pp. 47, 71, 77, 100; Verner et al. 1992, pp. 9–10, 60, 88; Moen and Gutierrez 1997, pp. 1281–1284).

CHAPTER 3: SPECIES ECOLOGICAL NEEDS

In this chapter, we discuss the habitat components that support CSO individuals and populations, CSO population needs, and overall species needs.

3.1 Habitat Components

In this section, we assess the best available information to identify the specific habitat components needed to support individual fitness at all life stages for CSO. For CSO, an individual must have adequate nesting, foraging, and roosting habitat to be successful, and for the purpose of this SSA Report, the components of nesting, foraging, and roosting habitat that we considered most significant include canopy cover, larger trees, and habitat heterogeneity. Forest heterogeneity is important to CSO as it provides protection from predators and extreme weather conditions, variable microclimates, and habitat for different prey species. Table 1 summarizes these habitat components by life stage and season. We acknowledge that these habitat components are not all-inclusive and there may be other components of nesting, foraging, and roosting habitat that are not being considered (such as prey). We also acknowledge that a history of fire suppression in the western United States, including throughout the CSO range, has caused many ecological changes that are not

fully understood (Mallek et al. 2013, p. 2) and are a significant departure from the natural range of variation in these forests(Safford and Stevens 2017, p. i). This includes, but is not limited to, model estimates that canopy cover was historically lower (less than 50%) than is currently observed today (Safford and Stevens 2017, p. 90) However, we chose to focus on habitat components for which there are available spatial data across the range of the species. Furthermore, prey is indirectly considered in our analysis since the primary CSO prey species also select for high canopy cover and coarse woody debris (Waters and Zabel 1995, p. 858), which are considered here as components of habitat heterogeneity. Populations of CSO require the same habitat components as individuals but at larger scales.

Table 1: Habitat components needed for all life history stages of the California spotted owl.

	Life History Stage			
Habitat Components	**Winter**	**Spring**	**Summer**	**Fall**
Canopy cover	Juveniles, Sub-adults, Adults	Hatchlings, Sub-adults, Adults	Hatchlings, Juveniles, Sub-adults, Adults	Juveniles, Sub-adults, Adults
Large Trees	Sub-adults, Adults	Eggs, Hatchlings, Sub-adults, Adults	Eggs, Hatchlings, Sub-adults, Adults	Sub-adults, Adults
Habitat Heterogeneity	Juveniles, Sub-adults, Adults	Hatchlings, Sub-adults, Adults	Hatchlings, Juveniles, Sub-adults, Adults	Juveniles, Sub-adults, Adults

3.1.1 Canopy Cover

Multi-layered, or complex, high canopy cover is considered an important resource for spotted owls because it provides cool shaded microclimates, camouflage/cover for protection from predators and extreme weather conditions, and habitat for prey species (Forsman 1975, pp. 4, 90, 105; Barrows 1981, p. 302; Forsman et al. 1984, p. 5). High canopy cover from tall trees is associated with higher probability of successful prey capture by CSO, while heterogeneity of forest types also facilitates prey capture (Zulla et al. 2022, p. 8). Furthermore, high canopy cover from tall trees is an important predictor for CSO nesting habitat (North et al. 2017, pp. 166, 172–175), and multi-layered high canopy cover around the nest tree and in territories is an important factor associated with CSO reproductive success (Hunsaker et al. 2002, pp. 693–699; Blakesley et al. 2005, pp. 1554, 1558–1562). Areas with canopy cover greater than 70% is considered optimal for CSO nest sites and occupancy sharply declines when canopy cover is less than 40% (Blakesley et al. 2005, p. 1559; Seamans 2005, pp. iii, 90, 100; Seamans and Gutiérrez 2007b, pp. 566, 568; Tempel et al. 2014a, pp. 2089, 2091, 2101, 2016, pp. 747, 759). Further, CSO in Yosemite National Park had territory centers with average values of 40% canopy cover in burned forests (Schofield et al. 2020, pp. 4–5).

3.1.2 Large Trees

Presence of large trees, defined as trees that are greater than 61 cm (24 in) dbh (Seamans and Gutiérrez 2007b, pp. 566, 571–574; Tempel et al. 2014a, p. 2094; Jones et al. 2018, p. 344), is important for CSO foraging, roosting, and nesting. California spotted owls tend to forage and roost in large trees, likely due to the canopy cover provided by large trees and the important resources

such as shelter and food that large trees provide for prey species (Laymon 1988, pp. 47, 71, 77, 100; Verner et al. 1992, pp. 9–10, 60, 88; Moen and Gutierrez 1997, pp. 1281, 1284). The presence of tall (>48 m (157 ft)) trees, and the canopy cover they provide, is the best predictor for CSO occupancy and areas with a high density of large trees is considered high quality habitat (Blakesley et al. 2005, pp. 1554, 1558–1562; North et al. 2017, pp. 166, 171–176). California spotted owls use a subset of large trees or snags as their nest trees (LaHaye et al. 1997, pp. 42, 47; Blakesley et al. 2005, pp. 1554, 1558–1562; Gutiérrez et al. 2017, p. 50) and the nest tree itself is critical for CSO reproductive success because it provides the space and structure needed for nests, along with protection from predators and inclement weather. California spotted owls do not build their own nest but rely on larger trees that provide multi-layered high canopy cover with open cavities (created as a result of fallen branches, woodpeckers, etc.), broken tops, platforms, and old raptor nests (Gutiérrez et al. 2020, "Habitat" and "Breeding" sections). The nest tree chosen within a territory is typically one of the oldest and largest live or dead trees within the nesting territory with many defects like cracks, disease scars, or decaying wood (Verner et al. 1992, pp. 6, 60, 71; North et al. 2000, p. 797).

3.1.3 Habitat Heterogeneity

The preferential use of mature forests with high canopy cover and large trees, as described above, is well-known for CSO (Gutiérrez et al. 2017, p. iii). However, there have been several recent studies showing the importance of other habitat types, habitat edges, and/or habitat heterogeneity (Atuo et al. 2019; Hobart et al. 2019; Kramer et al. 2021b; Zulla et al. 2022; Wilkinson et al. in prep.). These results may California spotted owl occupancy, colonization, adult survival, and reproductive success are all positively associated with the proportion of structurally complex forests (Franklin et al. 2000, p. 539; Blakesley et al. 2005, p. 1562; Tempel et al. 2014a, p. 2089, 2016, p. 747). The biological and physical components that create habitat heterogeneity and complex structure are areas of multi-layered high canopy cover, large trees, coarse woody debris, understory and mid-story vegetation, patches of burned habitat, riparian habitat, large diameter standing dead trees (snags), and some open areas within a home range.

Coarse woody debris (i.e. fallen dead trees and the remains of large branches on the ground) is an important habitat feature for CSO because it provides food, shelter, and protection for CSO prey species, especially woodrats (Waters and Zabel 1995, pp. 861–862; Pyare and Longland 2002, pp. 1016–1017; Innes et al. 2007, pp. 1523, 1526; Kelt et al. 2013, p. 1208). Coarse woody debris in areas of multi-layered high canopy cover is conducive for fungal growth, a food source for many CSO prey species (Verner et al. 1992, pp. 71–72; Pyare and Longland 2002, pp. 1016–1017).Rates of prey capture by CSO are observed to be higher in taller multilayered forests, in areas with higher vegetation heterogeneity, and near forest-chapparal edges (Wilkinson et al. in prep., p. 2). Similarly, CSO captured more prey in areas with more large trees and in areas with greater forest heterogeneity, i.e. a greater mixture of forest types (Zulla et al. 2022, pp. 7–8).There are a variety of habitats within a heterogeneous landscape that CSO use and which may provide specific resources. Studies have found that the size of a CSO home range increases as the heterogeneity, or number of different vegetation patches, increase (Williams et al. 2011, p. 333); the hypothesis is that there may be an optimal point of habitat heterogeneity for CSO beyond which territory quality declines (Williams et al. 2011, p. 333). Open areas (defined as forest with less than 40% canopy cover) can be important for foraging, although the probability of CSO site occupancy is lower in areas with more open areas and younger forest (Hobart et al. 2019, p. 197). Differences in habitat use by CSO at different scales are highlighted by analyses showing that GPS-tagged CSO select areas with relatively

high heterogeneity of seral stages except for the core of their home range (i.e. the nest location), where CSO selected for relatively homogeneous forest with large trees and closed canopies (Atuo et al. 2019, p. 302).

Low severity or patchy mixed severity wildfire is a historical natural occurrence throughout the range of the CSO, creating elements of a heterogeneous landscape under which CSO are adapted. There is evidence to suggest that more pyrodiverse landscapes support greater landscape heterogeneity (Steel et al. 2021, pp. 7–8; Stephens et al. 2021, p. 5). For example, in areas where woodrat is the primary prey species, a juxtaposition of mature forests and open canopy patches may promote higher prey diversity and abundance and northern spotted owls preferentially select for these areas (Zabel et al. 1995, p. 433, 2003, p. 1027; Ward and Noon 1998, p. 79; Franklin et al. 2000, p. 539). Burned areas can reduce the amount of high canopy cover available for owls, but studies have found that CSO forage on the edge of and within areas that have been burned at a range of severities (Bond et al. 2009, p. 1116, 2016, p. 1290; Eyes et al. 2017, p. 375) although typically avoiding larger areas of high-severity fire (Jones et al. 2016a, p. 304; Eyes et al. 2017, p. 383; Kramer et al. 2021a, p. 7). The negative impacts of current regime large-scale high-severity fires are further discussed in section 4.1 of the SSA Report. Riparian areas are also considered important, particularly for foraging habitat, even though they may not always exhibit high canopy cover and large trees (Meyer et al. 2005, p. 275; Irwin et al. 2007, p. 1189; Bond et al. 2016, p. 1290).

3.2 Population Needs

In this section, we define what a CSO population is and how we further divide populations into separate analysis units based on land management boundaries. The reason we further divide populations into analysis units is to conduct a more focused analysis of how different areas within each population contribute to that population's overall resiliency. We also define resiliency and identify the demographic factors that can be used to assess CSO analysis unit condition and population resiliency. As mentioned previously, populations of CSO have the same habitat needs as individuals but at larger scales and in the appropriate configuration.

3.2.1 Definition of a Population and an Analysis Unit

Within this SSA Report, we define a population as a group of interbreeding CSO that are more likely to breed among that group than outside of that group. We use information from genetic studies and habitat features to identify two CSO populations: one in the Sierra Nevada, and another in coastal and southern California (hereafter referred to as the coastal-southern California population).

In the western Sierra Nevada, habitat is relatively continuous, without significant gaps in distribution (Gutiérrez et al. 2017, p. xviii); however, in the eastern Sierra Nevada, habitat is more discontinuous with disjunct patches (Dilts 2022, pp. 5–9). Though CSO still have substantial gene flow within the Sierra Nevada (see section 2.2 Genetics). Further, there is limited gene flow to coastal or southern California, and large-scale fragmentation of suitable habitat divides the Sierra Nevada from this other population (Barrowclough et al. 2005, pp. 1114–1116). Barrowclough et al. (2005, p. 1114) found limited asymmetrical gene flow from Carmel, California (i.e., central California coast) to the Sierra Nevada, indicating that there has been some historical low-level interbreeding between these populations. This level of gene flow is not at a similar level to the gene flow

documented in areas within the Sierra Nevada. We are not aware of specific information about individual CSO moving between these two population areas.

In coastal and southern California, the CSO population consists of subpopulations distributed among discrete mountain ranges, resulting in habitat "islands" surrounded by unsuitable habitat (Verner et al. 1992, p. 187). Areas between these habitat "islands" that constitute the subpopulations are typically lowland desert scrub and chaparral that is unsuitable for CSO, or substantially modified by human-induced development and fragmentation (Verner et al. 1992, p. 187). Some of the subpopulations are separated by relatively narrow gaps, such as the gap between the San Gabriel and San Bernardino Mountains, while other gaps are more significant, such as the gap between the Northern and Southern Santa Lucia Mountains. Verner et al. (1992, p. 188) reported CSO nearest-neighbor distances in southern California that are as great as 45 miles. The Barrowclough et al. (2005) study described above did not calculate gene flow between the Carmel sample and any samples from southern California because gene flow was only calculated between geographically adjacent samples, and there were no southern California samples that fit those criteria. California spotted owls in coastal and southern California are less well-studied than those in the Sierra Nevada, but there is a notable lack of documented CSO movement between the coastal and southern subpopulations and we are not aware of any dispersal between them. This population is also described in the literature as being a presumed metapopulation (Verner et al. 1992, pp. 187–206; LaHaye et al. 1994, p. entire; Gutiérrez et al. 2017, p. 241) despite the documented lack of connectivity, even though dispersal among populations is a defining characteristic of a metapopulation (see Hanski and Gilpin 1991 for more on metapopulation theory). However, spatial structure of a metapopulation within and among subpopulations is critical for metapopulation functioning, and available evidence does not document successful dispersal between the San Bernardino, San Gabriel, and San Jacinto Mountains, which are adjacent mountain ranges, indicating that if mixing does occur it is very rare (LaHaye et al. 2001, p. entire, 2004, p. entire; Gutiérrez et al. 2017, pp. 242, 250). Further, Gutiérrez et al. (2017, pp. 241–242, 250) discusses that not all subpopulations within the metapopulation have equal likelihood of "blinking out" or being rescued/recolonized by other subpopulations, which are important components of metapopulation theory. Within the coastal-southern California population, the subpopulation inhabiting the San Bernardino and San Gabriel mountains is the largest subpopulation and is the subject of most ecological studies. The persistence of this subpopulation has been identified as important for persistence of the coastal-southern California population (Verner et al. 1992, pp. 197–206), which is discussed more in Chapter 5: Current Condition.

To conduct a more focused analysis of how different portions of each population's ranges contribute to that population's overall resiliency, we further divided the Sierra Nevada and coastal-southern California populations into analysis units (see Figure 4). Table 2 provides the size of each analysis unit and the proportion of land ownership between federal, state, local, and private entities. We chose analysis units roughly based on public land management boundaries because of varying demographic data and management strategies across the range. Dividing the population up into analysis units based on land management boundaries allows a better assessment of the varying conditions across the range. We identified a total of 15 analysis units.

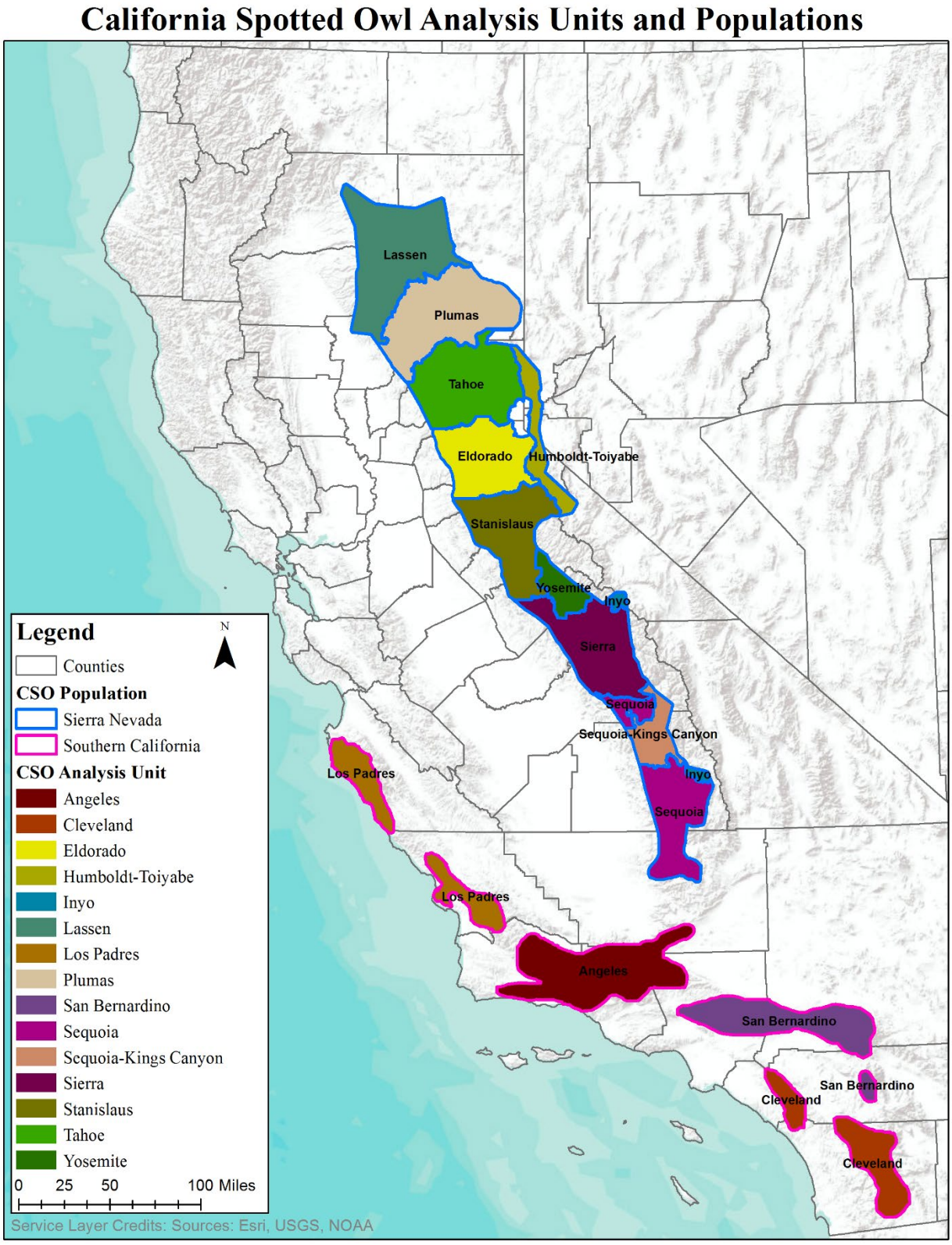


Figure 4: California spotted owl analysis units for the Species Status Assessment. Analysis units were defined broadly using public land boundaries, incorporating surrounding private lands.

Table 2: California Spotted Owl Analysis Unit Size and Land Ownership Percentage using the digital file, BLM CA Land Status – Surface Management areas dated September 23, 2019, to calculate proportions of federal, state, local government, and private lands within the species' range.

Analysis Unit	Size of Analysis Unit (hectares)	Proportion Federal Land	Proportion State Land	Proportion Local Land	Proportion Private Land
Sierra Nevada					
Lassen	774,456	51%	<1%	<1%	48%
Plumas	693,786	70%	1%	0%	28%
Tahoe	625,183	59%	<1%	0%	40%
Eldorado	467,257	63%	<1%	<1%	37%
Humboldt-Toiyabe	116,901	85%	2%	0%	13%
Stanislaus	499,536	67%	<1%	<1%	32%
Yosemite	138,873	99%	0%	<1%	<1%
Sierra	534,163	86%	<1%	0%	14%
Sequoia-Kings Canyon	180,702	91%	<1%	0%	9%
Sequoia	498,606	84%	<1%	0%	15%
Inyo	41,771	98%	0%	0%	2%
Coastal-Southern California					
Los Padres	342,617	44%	3%	<1%	53%
Los Padres-Angeles	732,520	72%	<1%	<1%	28%
San Bernardino	505,937	79%	<1%	<1%	20%
Cleveland	360,320	48%	5%	<1%	46%

3.2.2 Resiliency

Resiliency is the ability of a species to withstand stochastic events, the normal year-to-year variations in both environmental conditions (i.e., temperature, rainfall, and periodic disturbances such as fires, floods, and storms) and demographic conditions (i.e., mortality, fecundity) (Redford et al. 2011, p. 40). Determined by the size and growth rate of the populations comprising the species, resiliency can be evaluated to gauge the ability of a species to weather the natural range of favorable and unfavorable conditions.

Populations of CSO must have adequate amounts of nesting, foraging, and roosting habitat containing the habitat components described above in sufficient amounts and the appropriate configuration on the landscape to support a stable or increasing growth rate. They also need connectivity between territories and home ranges. Populations meeting these requirements are better able to withstand stochastic events. In many instances, however, data are insufficient or completely lacking regarding a population's size and growth rate. In the absence of such data, it can be reasonable to examine other characteristics that may serve as surrogate indicators of general population health and, subsequently, resiliency. Essentially, an assessment of the availability of a species' identified needs (e.g., suitable habitat, food, breeding sites) may allow us to make

assumptions about the potential resiliency of any given population. However, unless there is a documented positive correlation between species needs availability and a population's known demographic condition, the uncertainty regarding such assumptions must be made clear.

3.2.3 Demographic Factors Influencing Analysis Unit Condition and Population Resiliency

In this section we describe the demographic factors that are being considered in this SSA Report as important for CSO, including natal dispersal, survival, fecundity, occupancy, and population growth. We describe the importance of each demographic factor to CSO persistence and how the habitat needs discussed in the previous section influence these factors. Figure 5 is a conceptual model that shows the relationship between habitat needs and demographic factors, which affect analysis unit condition and, ultimately, a way to measure population resiliency.

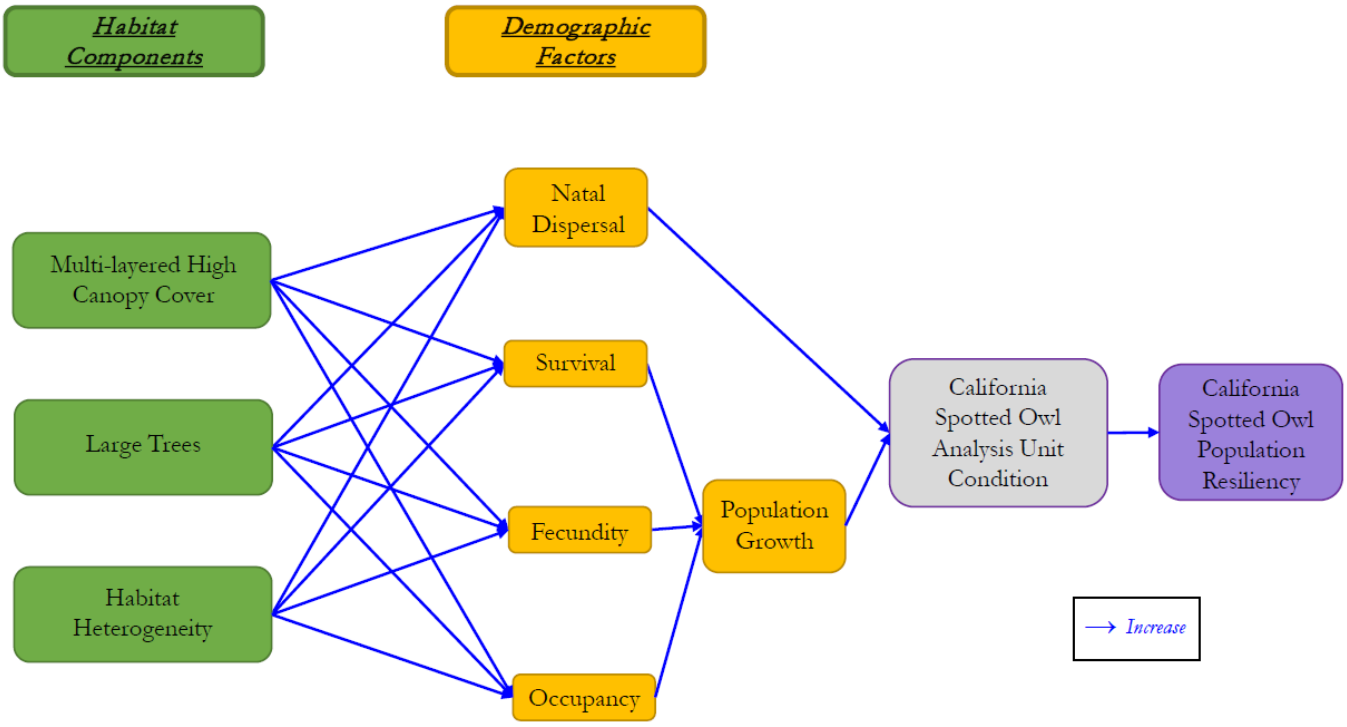


Figure 5: Conceptual model showing the relationship between habitat needs and demographic factors, and how they influence analysis unit condition and resiliency of California spotted owl populations. The blue arrows represent influences showing relationships between varying needs.

3.2.3.1 Natal Dispersal

As discussed in the "Life History" section of the SSA Report, natal dispersal is the primary mechanism for juvenile and sub-adult birds to find their own territory, and throughout this document when we refer to dispersal it means natal dispersal. Dispersal decreases the likelihood of incestuous mating, which is rarely observed in spotted owls (Carlson et al. 1998, pp. 562–563; Forsman et al. 2002, p. 2). For dispersal to be successful, many of the habitat components must be present within the areas CSO disperse to. Canopy cover, large trees, and coarse woody debris, all

must be available in sufficient amounts and the appropriate configuration on the landscape (i.e., provides heterogeneity) for juveniles or sub-adults to successfully settle into a territory to begin breeding.

There is little available information about dispersal and dispersal habitat between the areas we define as CSO populations and analysis units within this SSA report. Dispersal habitat is described for northern spotted owl as 50% of the forest matrix outside of activity centers in stands with an average of 28 cm (11 in) dbh and 40% canopy closure (Thomas et al. 1990, p. 15). This contrasts with dispersal for Mexican spotted owls, which may move across large areas of unforested habitat to access suitable habitat on different mountain ranges (Gutiérrez et al. 1995, p. 5, 2017, p. 242). It is unknown how far CSO will disperse across unsuitable habitat to find a new territory, but adult northern spotted owls have been found to occasionally move long distances if forced out of a territory (Forsman in litt. 2018, p. 22).

3.2.3.2 Survival

Survival is defined as individuals in a population persisting across years. As discussed in the "Life History" section of the SSA Report, the CSO is a long-lived species with low reproductive rates. Survival, particularly adult survival, is closely linked to population growth in spotted owls and is important for maintaining population resiliency (Seamans and Gutiérrez 2007a, p. 57; Blakesley et al. 2010, p. 27). Adult CSO have high annual survival rates ranging from 0.796-0.814 in different study areas within analysis units in southern California (LaHaye et al. 2004, p. 1056; Franklin et al. 2004, p. 22), and 0.811-0.891 in study areas within analysis units in the Sierra Nevada (Blakesley et al. 2001, p. 671, 2010, p. 10; Franklin et al. 2004, p. 22; Tempel et al. 2014b, p. 92). In comparison, juvenile survival is difficult to estimate due to dispersal, and has been found to be low, ranging from 0.087-0.333 in study areas within analysis units in the Sierra Nevada (Blakesley et al. 2001, p. 671; Tempel et al. 2014b, p. 92), and 0.368 for southern California (LaHaye et al. 2004, p. 1056). For northern spotted owl, juveniles tend to have high mortality during the dispersal phase (Miller 1989, pp. 41–44; Forsman et al. 2002, p. 18).

All the habitat needs discussed above influence survival. For example, survival is related to the amount of forest dominated by medium to large trees, high canopy cover, and habitat complexity (Blakesley et al. 2005, p. 1554; Tempel et al. 2014a, pp. 2089, 2098; McGinn et al. 2022, p. 9). In northern spotted owls, forest heterogeneity is correlated with higher survival rates (Franklin et al. 2000, p. 539). Weather patterns can also affect survival in both CSO (Seamans and Gutiérrez 2007a, p. entire) and northern spotted owl (Glenn et al. 2011, entire). Further impacts to survival will be discussed in Chapter 4 Influences to Viability of the SSA Report.

3.2.3.3 Fecundity

Fecundity is defined as the ability to produce offspring and is measured by the number of viable female offspring that an individual can produce over a specific time period. Although CSO are considered to have low reproductive output, or number of young fledged per year, reproduction is essential for population persistence and species viability. As discussed in the "Life History" section of the SSA Report, CSO do not always reproduce every year (although they can) and only lay 1–3 eggs when breeding does occur. Annual reproductive output, measured by presence or absence

of offspring in a nest, for female CSO in a demographic study in the Sierra Nevada was found to range from 0.478–0.988 (Blakesley et al. 2010, p. 1). Reproduction throughout all the demographic studies (see 5.1 Current Condition Summary of Methods for more information on the demographic studies) has ranged from no reproduction within a study area to nearly all birds reproducing in a study area in a particular year (Franklin et al. 2004, pp. 32–33; Seamans and Gutiérrez 2007a, p. 65; Blakesley et al. 2010, p. 17; MacKenzie et al. 2012, p. 597; Tempel et al. 2014b, p. 91; Stoelting et al. 2015, p. 46). Fecundity, measured as female young produced per female annually, has been found to range from 0.284–0.409 in the Sierra Nevada and to be 0.362 in southern California (Franklin et al. 2004, pp. 11, 23).

Many of the habitat components discussed in the previous section of this SSA Report influence fecundity. Reproductive output decreases as non-forest habitat increases within the area around the nest, and nest success increases as the presence of large remnant trees within the nest stand increases (Blakesley et al. 2005, p. 1554). Reproduction is positively correlated to the foliage volume above the nest tree (North et al. 2000, p. 797), although forest heterogeneity is also important for reproduction (Franklin et al. 2000, p. 539; Tempel et al. 2014a, p. 2089; McGinn et al. 2022, p. 9) and foraging (Zulla et al. 2022, pp. 7–8). Annual variation in weather also plays a role in reproductive success (North et al. 2000, p. 797; Seamans and Gutiérrez 2007a, p. 57; MacKenzie et al. 2012, p. 597; Stoelting et al. 2015, p. 46). For example, CSO experienced increased fecundity when a dry breeding season followed a previously wet year (LaHaye et al. 2004, pp. 1056, 1062). Although survival of breeding CSO is an important factor that is closely connected to population growth, reproductive output may be more influential to population growth because it varies more than adult survival (Blakesley et al. 2001, p. 667; Seamans and Gutiérrez 2007a, p. 57).

3.2.3.4 Occupancy

California spotted owl occupancy in this SSA Report is defined as the stable (not transient) presence of at least one adult within a territory. California spotted owls select and defend territories in which they spend most of their life. California spotted owl pairs will only reproduce once they have established an occupied territory. The measure of occupancy has been found to be strongly correlated with regional abundance of CSO and can provide reliable inferences on population trends (Tempel and Gutiérrez 2013, pp. 1093–1093). Since the Verner et al. 1992 CSO Assessment of Current Status report, occupancy has been well studied in study areas corresponding to four analysis units within the Sierra Nevada and at one analysis unit in southern California providing long-term demographic information (Gutiérrez et al. 2017, pp. 79–85). The occupancy data that have been collected have been used to assess trends in population change, which will be discussed further in the "Current Condition" section of the SSA Report (Franklin et al. 2004; Tempel et al. 2014b, p. entire; Conner et al. 2016).

Many of the habitat needs discussed in the previous chapter of this SSA Report need to be present in order for CSO to occupy a territory. Occupancy is generally higher and more consistent with an increasing proportion of the territory containing large trees and high canopy cover (Blakesley et al. 2005, p. 1554; Seamans and Gutiérrez 2007b, p. 572; Roberts et al. 2011, p. 610; Tempel et al. 2014a, p. 2089; Gutiérrez et al. 2017, p. vxii). Habitat alteration can negatively impact occupancy for CSO because it removes the habitat needs of large trees and multi-layered high canopy cover (Seamans and Gutiérrez 2007b, p. 566); however, the degree of alteration can have

varying effects on occupancy (see Chapter 6 Influences to Viability). As the proportion of forest types that are not used for nesting (smaller, similar-aged young trees) increases, occupancy tends to decrease (Blakesley et al. 2005, pp. 1554, 1560).

3.2.3.5 Population Growth

California spotted owl population growth in this SSA Report is defined as the change in the number of individuals within a particular study area, which correspond to our analysis units. Population growth is determined by the demographic factors of survival, fecundity, and occupancy, with fecundity likely the most influential because it is more variable (Blakesley et al. 2001, p. 667, 2010, p. 27; Seamans and Gutiérrez 2007a, p. 57, b, p. 566; Tempel and Gutiérrez 2013, pp. 1093–1094; Gutiérrez et al. 2017, p. 99). Population growth is variable throughout study areas in the Sierra Nevada where we have available information, with documented declines ranging from -50% to -31% in some study areas and a population increase of 25% in another (Tempel et al. 2014b, pp. 86, 90–92; Conner et al. 2016, p. 15)(see 5.3.1 Sierra Nevada Population for more information on known population trends). The only available demographic data for southern California is from the San Bernardino National Forest. A population decline of -9% was observed from 1987–1998, with more recent occupancy analyses showing further declines in population size (LaHaye et al. 2004, pp. 1056, 1064; Tempel et al. 2022, pp. 20, Table 5). All habitat components described in the previous chapter need to be present for positive CSO population growth, as described in further detail in the survival, fecundity, and occupancy sections above.

The difference in population rates between occupancy and mark-recapture models could be due to several reasons. For example, occupancy models may not be as sensitive to real changes in population growth, as they measure if a territory is occupied without taking into account to the number of owls inhabiting that territory (an occupied territory was counted as one that included a single owl, a pair of owls, or more than a pair of owls) (Conner et al. 2016, pp. 13–15). Differences in population trends measured in the two Eldorado studies were likely due to the inclusion of additional years in the 2014 study, as well as increased number of territories occupied only by single owls rather than pairs in that analysis (that is, the loss of half of a pair would result in lower fecundity and thus lower population growth) (Tempel et al. 2014b, p. 93). There is some evidence that population declines in these study areas have not been continuous; one study measured stationary population growth rates from 1998–2005, with the greatest increase in survival from 2000–2005 (Blakesley et al. 2010, pp. 17–18). However, the best available evidence does indicate that owls in the study areas have experienced an overall decline in population. None of the models have forecasted whether these trends will continue into the future, and these existing models cannot be used to forecast future trends (Franklin et al. 2004, p. 34).

3.3 Species Needs

At the species level, we assess the redundancy and representation of the entire CSO range to better understand the viability of the species. Viability is defined as the ability of CSO to sustain populations in the wild over time. Redundancy is the ability of a species to withstand catastrophic events and representation is the ability of a species to adapt to changing environmental conditions. Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (the 3Rs).

3.3.1 Redundancy

Redundancy is the ability of a species to withstand catastrophic events, i.e., natural or anthropogenic stochastic events that would result in the loss of a substantial component of the overall species population. Such a loss could be of one or more populations of a species which is comprised of multiple populations, or the catastrophic loss of a substantial number of individuals from a species with only a single population. However, redundancy is not simply a measure of the total number of individuals or populations of a species, but instead must also be evaluated in the context of an assessment of reasonably plausible catastrophic events. For example, a species with numerous small populations does not necessarily translate to a greater ability to withstand catastrophic events if those populations are very close together, and the only reasonably plausible potential catastrophe is one that would affect them all equally. Conversely, a species with only one population, but one which is very large and widely distributed, could well have a high ability to withstand a catastrophic event that would only affect a small percentage of the overall population. Therefore, our characterization of a species' redundancy takes into consideration both an assessment of the size and distribution of its population(s), and an evaluation of the kinds and likelihood of reasonably plausible catastrophic events to which the species could be exposed.

For CSO, we evaluate redundancy by considering the number of resilient populations distributed across the species' range. Having resilient populations distributed across the range increases the species ability to withstand catastrophic events. Threats, including those that could be catastrophic, are discussed more in Chapter 4.

3.3.2 Representation

Representation is the ability of a species to withstand and adapt to long-term changes in environmental conditions (i.e., significant changes outside the range of normal year-to-year variations). The measure of a species' representation may be determined by the breadth of genetic diversity within and among populations; however, in the absence of information on a species' genetic diversity, we may also evaluate a species' known environmental diversity (i.e., the diversity of environmental conditions over which it is known to occur) as an alternative measure of its ability to withstand and adapt to long-term changes.

For CSO, we evaluate representation by considering the distribution of s populations across their various ecological settings and whether those populations are able to maintain adequate amounts of genetic diversity. Having a variety of ecological settings that the species can occupy and a breadth of genetic diversity increases the species ability to withstand and adapt to long-term environmental changes.

CHAPTER 4: INFLUENCES TO VIABILITY

In this chapter, we evaluate the significant past, current, and future influences that are impacting CSO resiliency, redundancy, and representation. These influences impact the species ecological needs, ultimately affecting the viability of the species.

4.1 Wildfire

Fire is a natural part of CSO habitat (Verner et al. 1992, pp. 247–248) and is necessary for maintaining heterogenous forests. Overall, wildfire accounts for a greater proportion of live tree mortality than any other activity (e.g., timber harvest, development) in California (Sleeter et al. 2011, pp. 262, 264). Wildfire and associated tree mortality can be beneficial or detrimental for CSO depending on scale and severity. Fire severity is often categorized as low, moderate, or high, with low severity fire defined as areas of surface fire with little change in canopy cover and little mortality of the structurally dominant vegetation, moderate severity as a mixture of effects on the structurally dominant vegetation, and high severity as areas where the dominant vegetation has high to complete mortality. Areas that experience fires with predominantly low to moderate severity burn patterns with small patches of high-severity fire scattered throughout the fire perimeter can increase forest heterogeneity, ultimately result in higher prey densities, increase amounts of forest edge for foraging, which benefits CSO, and provide for unburned refugia within the fire perimeter that have higher tree survival and more vegetative cover during the immediate postfire years (Roberts et al. 2011, p. 610; Lee et al. 2012, p. 792; Bond et al. 2013, pp. 114, 122; Eyes et al. 2017, p. 384; Blomdahl et al. 2019, pp. 1046, 1048, 1049). There is also evidence to suggest that more pyrodiverse (i.e., spatial or temporal variability in fire effects; (Jones and Tingley 2021, p. 1) landscapes support greater landscape heterogeneity which may promote greater biodiversity (Steel et al. 2021, pp. 7–8; Stephens et al. 2021, p. 5). For example, in areas where woodrats are the primary prey species, a juxtaposition of mature forests and open canopy patches promotes higher prey diversity and abundance, and northern spotted owls preferentially select for these areas (Zabel et al. 1995, p. 433, 2003, p. 1027; Ward and Noon 1998, p. 79; Franklin et al. 2000, p. 539).

(Kramer et al. 2021a, pp. 8–9) studied CSO in a fire managed landscape (i.e., National Park) and concluded that CSO selected areas of low-severity fire and older burned areas (e.g., fires 16-40 years old), demonstrating owls are likely adapted to frequent low-severity fire. Although burned areas can reduce the amount of high canopy cover available, studies have found that CSO forage on the edge of and within areas that have been burned at a range of severities (Bond et al. 2009, p. 1116, 2016, p. 1290; Eyes et al. 2017, p. 375) although typically avoiding larger areas of high-severity fire (Jones et al. 2016a, p. 304; Eyes et al. 2017, p. 383). Further, Lesmeister et al. (2019, p. 12) concluded there was little effect to nest or roost habitat from low-severity fire in northern spotted owl range. Thus, many researchers advocate for the use of ecologically beneficial fire to help sustain CSO habitat and report that low to moderate severity fire minimizes the effects of future high-severity wildfire (Stephens et al. 2019, pp. 395–396, 2020, p. entire, 2021, p. 5; Taylor et al. 2022, p. 4); also see 4.5. Fuels Reductions and Forest Management).

However, large-scale high-severity fires have a detrimental effect on both CSO and its habitat. Large-scale high-severity fire (i.e., a megafire) is generally defined as over 10,000 ha (24,711 ac) of area burned with 75–100% canopy mortality (Jones et al. 2016a, p. 300; Linley et al. 2022, pp. 6, 8). These megafires can degrade or destroy CSO habitat, completely incinerating large trees and canopy cover (Eyes 2014, p. ii; Roberts et al. 2015, pp. 112–115; Jones et al. 2016a, pp. 300–305). Wan et al. (2020, p. 7) determined habitat suitability for northern spotted owls decreased postfire and depended on fire severity (i.e., higher fire severity resulted in greater declines of habitat suitability); thus, megafires have a greater potential to alter the availability of suitable habitat.

The loss of habitat from large-scale high-severity fires also results in direct impacts to CSO individuals and populations. As megafires alter the number of large trees (including nest trees), multi-layered high canopy cover, forest heterogeneity, and patch size, CSO dispersal, fecundity, and occupancy are subsequently reduced. It has been observed that large patches of high-severity fire significantly reduce colonization (dispersal), occupancy, and habitat use across the CSO range (Eyes 2014, p. 42; Tempel et al. 2014a, p. 2089; Jones et al. 2016a, pp. 300, 303–305; Eyes et al. 2017, pp. 381, 384)(Jones et al. 2019, p. 26, 2020b, p. entire, 2021b, p. 5; Schofield et al. 2020, pp. 5–6; Tempel et al. 2022, p. 13) and for other subspecies (Rockweit et al. 2017, p. entire; Lesmeister et al. 2019, p. 13; Duchac et al. 2021, p. 12). Fires may cause direct mortality to eggs and juveniles during the nesting season and fast-moving fires also have the potential to cause direct mortality to adult individuals (Jones et al. 2016a, p. 305). No data are available on how many CSO are killed annually by direct impacts of large-scale high-severity fire. Thick smoke can debilitate birds and low, thick smoke may also prevent birds from flying away to escape the fire area (Epanchin et al. 2002, p. 141). Although most birds are able to move to escape direct morality from fires, smoke from fires can impact birds by damaging their lungs (Verstappen and Dorrestein 2005, p. 139). While many species have existed with frequent fire over evolutionary time, there are novel stressors from megafires and extreme smoke events that may act as an additional selective pressure on certain species (Nimmo et al. 2021, p. 5689). It is well-known that birds are more sensitive to air pollution than other taxa (Brown et al. 1997, entire). There is limited research on the effects of wildfire smoke on wildlife in general, but there is clear evidence that smoke can have both acute and chronic health impacts on a variety of taxa, which may ultimately affect demographic rates (Sanderfoot et al. 2021, p. 13). For example, some birds may be more sensitive to the effects of fire when they are caring for young, which can influence nest success and subsequent recruitment (Cahill and Walker 2000, pp. 111–112).

There are several publications that conclude there are no negative effects of high-severity fire for CSO (Lee and Bond 2015, p. entire; Hanson et al. 2018, p. entire, 2021, p. entire; Lee 2018, pp. 12, 16, 2020, p. entire). However, many researchers such as (Jones et al. 2019, p. entire), (Jones et al. 2020b, p. entire), and (Jones and Peery 2019, p. entire) identified several errors, data misrepresentations, and inaccurate conclusions drawn from these owl studies (see previous sentence for citations, and for a larger discussion on misinformation about wildfire). We also recognize that (Jones and Tingley 2021, p. 10) suggest that rather than a binary discussion of high-severity fire and owl use patterns (i.e., owls either use high-severity fire or they do not), focusing instead on forest heterogeneity, pyrodiversity, and severe fire patch size interaction may better explain spotted owl use patterns rather than simply the presence of high-severity fire. There are a number of other publications detailed in (Hagmann et al. 2021, pp. 17–21, Tables 3-6) that also claim there is uncertainty about historical forest conditions, fire regimes, fire frequency, and fire severity, and purport that tree densities and amount of high-severity fire are not outside the natural range of variation expected for western forests. Hagmann et al. (2021, entire) discuss the inaccuracies with these publications (pp. 17-21, Tables 3–6) and conclude they do not represent the "best available science" because the authors do not account for ecological differences in site conditions, they make inappropriate comparisons, and overall use less accurate data sources, methods, or other errors (pp. 16-21). We acknowledge this disagreement in the literature. While we have analyzed all of the above sources, we observe that the vast majority of science discussed in this SSA Report that investigated the effects of fire on CSO (Jones et al. 2020a, p. entire) concludes that, overall, spotted owls avoid

large patches of high-severity fire and that high-severity fire is increasing throughout California and the western United States. Current conditions in the CSO range may contribute to ongoing fire risk, and depending on the portion of the range and the land manager, fire management activities may vary (see 4.5 Fuels Reductions and Forest Management). Decades of fire suppression have led to overall higher canopy cover from small and medium trees, higher dead biomass density, and more surface fuels in forests of the western United States (Verner et al. 1992, pp. 247–248; Agee and Skinner 2005, p. 83). The historical fire return interval for the Sierra Nevada was around 11–16 years, but fire suppression over the last 100 years has led to a change in fire behavior of larger, more severe fires in recent years (Safford and Stevens 2017, pp. v–vi). The multi-layered high canopy cover and biomass provide important habitat for the CSO but also tend to increase the vulnerability of forests to high-severity fire (Verner et al. 1992, pp. 251–258; Agee and Skinner 2005, p. 83) in present day fire-suppressed forests. The higher fuel loads, particularly large dead wood like snags and logs tend to burn at higher severity as densities increase (Lydersen et al. 2019, p. 7). In a recent megafire, dead biomass directly contributed to the fire effects observed with areas burned at high severity associated with areas with high amounts of dead biomass pre-fire (Stephens et al. 2022, p. 8). On top of the higher fuel loads, extended droughts and longer wildfire seasons have led to larger and more severe fires in the CSO range and throughout western North America (Miller and Safford 2012, p. 41; Mallek et al. 2013, p. 1; Nigro and Molinari 2019, p. 20; Parks and Abatzoglou 2020, p. 4; Safford et al. 2022, p. 12). In addition, in 2020 and 2021 over 1 million ha (2.4 million ac) burned in California, resulting in more area burned over these two years than in the past seven years of all California fires combined (Safford et al. 2022, p. 5). This amount is on par with the 1.8 million ha (4.4 million ac) that burned in an average in year in California prior to fire suppression practices brought with Euroamerican settlement in (Safford et al. 2022, p. 5). The acreage burned at high severity in 2020 is nearly three to six times higher when compared to historical conditions prior to Euroamerican settlement (Safford et al. 2022, p. 17). Thus, wildfire itself is not a novel disturbance for CSO, but rather the amount burned at high severity. Further, an increase in high severity fire changes how fire interacts with important habitat features for CSO. For example, fire often killed trees that would subsequently serve as CSO nests. However, large patches of high severity burn hotter and can end up entirely consuming the features important to CSO. Between the years of 2000–2014, 7% of CSO suitable nesting habitat (a total of 85,046 ha (210,153 ac) out of 1,166,560 ha (2,882,633 ac)) was burned either partially at moderate severity (typically 25-50% tree basal area mortality) or entirely at high severity (typically >75% tree basal area mortality), causing ≥50% tree basal area mortality and reducing canopy cover to <25% (Stephens et al. 2016, pp. 1, 9).

The size and severity of a fire determines how much it will impact CSO at the population level. If a high-severity fire occurs in a large enough area, it can eliminate entire territories or home ranges of CSO, displacing individuals that may or may not establish a new territory (Jones et al. 2016a, pp. 300–305). Overall, CSO avoided severely burned (>75% overstory mortality) forest after the 2014 King Fire, one of the first megafires in the Sierra Nevada, and severe fire patch size use varied depending on the quantity of severe fire in their home range (Jones et al. 2020b, p. 1206). Little information yet exists from the megafires of 2020 and 2021 that occurred in the western United States, but a few recent observations of northern spotted owls have documented nests at the edges of high-severity fire patches surrounded by post-fire foraging habitat; the nests themselves were in locations with low- to moderate-severity with nest trees containing dead needles (Hunter in

litt. 2022; Chow in litt. 2022; Siedel in litt. 2022). Some of these nest locations are adjacent to riparian zones that burned at low- and moderate-severity. Often riparian zones burn at lower fire severities; thus, they may serve as refugia for wildlife, but very thick riparian zones may diminish the protective effects of increased moisture making them vulnerable to burn at high severity (Dwire and Kauffman 2003, p. entire; North 2012, p. entire). Although some of these areas that have experienced moderate- to high-severity fire around the nest may provide the canopy cover that northern spotted owls need for one to two years postfire (through dead leaves or needles still present on trees), it is uncertain if northern spotted owls will persist in these locations as trees drop their leaves or snags fall to the ground. Site occupancy by CSO after wildfire appears to be a function of the amount of suitable habitat remaining after the fire (Gutiérrez et al. 2017, p. xxiii). If habitat becomes unsuitable, it takes decades for large trees to reestablish on the landscape. Based on fire activity and anticipated trends over the next 75 years, the cumulative amount of nesting habitat burned at ≥ 50% tree basal area mortality will exceed the total existing habitat in the Sierra Nevada (Stephens et al. 2016, pp. 1, 12). In other words, the loss of suitable CSO habitat would exceed the rate of new forest growing post-fire (Stephens et al. 2016, pp. 11–13). Thus, future habitat persistence for CSO is concerning given that high-severity fire appears to be increasing in the CSO range across all lands (both public and private) occupied by CSO and throughout the western United States (Parks and Abatzoglou 2020, pp. 4–5). When private lands are considered separately, the odds of high severity fire occurring on industrially managed forests and adjacent lands were 1.8 and 1.4 times higher, raising some concern over CSO persistence on private lands (Levine et al. 2022, p. 4).

In the Sierra Nevada, the proportion of high severity fire throughout the CSO range has dramatically increased in recent years. The proportion of high-severity fire in California montane forests in 2020 was on average 43–76% higher than the combined average between 1984 and 2008, and was three to six times higher than the estimates of pre-Euroamerican settlement (Safford et al. 2022, p. 17). In a 2022 analysis by the U.S. Forest Service Pacific Southwest Research Station, between 1984–2019, 2,679,044 acres burned throughout CSO range in the Sierra Nevada with 784,820 acres burned at high severity (Keane in litt. 2022, p. 3). In contrast, between 2020 and 2021 2,131,593 acres burned throughout the CSO range with almost 899,000 of those acres at high severity (Keane in litt. 2022, p. 3). This illustrates how megafires that burned in 2020 and 2021 burned more habitat at high severity in two years than fires over the past three and a half decades. In addition, between 1984 and 2021 a total of 50 percent of California spotted owl PAC acres have been impacted by wildfire, with 56% of that total burned in 2020 and 2021. Further, 65% of the 56% that burned between 2020 and 2021 burned at high severity (Keane in litt. 2022, p. 5). Because individual CSO are displaced from areas where the entire PAC or majority of the PAC has burned at high severity, it is unlikely the species will continue to persist in these areas until the habitat can recover, which can take decades. Protected Activity Centers are designations made by the Forest Service to protect the best available 121 ha (300 ac) of habitat in as compact of a unit as possible around a nest tree (see 4.9 Regulatory Mechanisms and Management Actions for a further description of PACs).

The Service conducted a fire severity analysis within the entire CSO range as defined in this SSA Report. We used the Monitoring Trends in Burn Severity (MTBS) data for 1984-2020 for our fire severity analysis. This data is managed by the U.S. Forest Service Geospatial Technology and

Applications Center and the U.S. Geological Survey Center for Earth Resources Observation and Science, and assessments are done approximately one year after the fire. We used Rapid Assessment of Vegetation Condition after Wildfire data (GTAC 2022) for 2021 fires which tends to overestimate fire severity since the assessment is done within the first few months after the fire stops burning, which may not account for trees that survived the fire after winter precipitation and a spring growing season (Hanson and North 2009, p. 861). This program is also managed by the U.S. Forest Service Geospatial Technology and Applications Center. As described in 4.1 Wildfire earlier in this section, low severity fire is defined as areas of surface fire with little change in canopy cover and little mortality of the structurally dominant vegetation, moderate severity as a mixture of effects on the structurally dominant vegetation, and high severity as areas where the dominant vegetation has high to complete mortality. We considered high severity fire >75% mortality. We calculated the proportion of low, moderate, and high severity fires within CSO range and determined fire has been steadily increasing with a large increase in recent years, leading up to the current condition. We used zonal statistics and tabulate area functions in ArcMap 10.8.1 and R for burn severity calculations. Figure 6 shows the amounts of habitat that have burned at low, moderate, and high severity within the CSO range from 1984 to 2021. This figure and Table 3 provide values of the amount of habitat that has been impacted by wildfire, including high-severity fire, the general trend of fire amount and severity, and a running total of area burned. Additional tables showing fire severity calculations by analysis unit are presented in Appendix I. It represents the variation over years, the proportion of wildfires that burn at high severity vs. moderate or low severity, and the amount of habitat that can be lost within a year to high severity fire. The fire values in Figure 6 represent total area burned and include areas that have burned more than once. Of the CSO range, approximately 47% burned between 1984 and 2021, with 15% at high severity. Most of the area burned at high severity occurred in 2020 and 2021, with 2% and 4%, respectively (see Table 3). Figure 7 shows wildfire locations and severity within the CSO range from 1984 to 2021. It provides a visual of the location and scale of fires within the CSO range. We expect that the pattern of both area burned and wildfire severity will continue or increase into the future. An existing dataset from the California Department of Forestry and Fire Protection examined the potential threat of future wildfire in California and is displayed in Figure 8. Megafires may be more likely to occur, and the likelihood is higher in areas shown in the map as higher threat categories (Safford et al. 2022, p. 17; Taylor et al. 2022, p. 1). To develop the California Wildfire Threat data, the California Department of Forestry and Fire Protection combined fire frequency, or the likelihood of a given area burning, with potential fire behavior to create four threat classes ranging from moderate to extreme. This dataset covers through 2014, so does not consider how the recent fires from 2014 to 2021 affect future fire threat. The majority of the CSO range occurs within the very high wildfire threat category (see Figure 8). Much of the southern California range of CSO falls within the extreme fire risk.

Some regulatory mechanisms and conservation measures can reduce the potential severity or scale of wildfires. Wildfire fuel reduction treatments, for example, prescribed fire and mechanical thinning, can reduce the amount or degree of spotted owl habitat alteration from a high-severity fire, and a balanced approach to fuel reduction treatments may ensure suitable CSO habitat is maintained (see Section 4.5) (Jones et al. 2016a, p. 305; Service 2017, pp. 24–25; Chiono et al. 2017, p. 1; Jones et al. 2021a, p. entire). The 2004 Forest Service Sierra Nevada Forest Plan Amendment has a goal of actively restoring fire-adapted ecosystems by reducing unnaturally dense conditions, but there are

also measures in place in the framework to avoid management actions within CSO activity centers to the greatest extent possible (Forest Service 2004, pp. 34–35) (see 4.9 for more information on Forest Plans). Fuel reduction treatments are actively taking place on Forest Service land, but special considerations including the timing of treatments with the breeding season and the methods that are used are evaluated to avoid impacts to owls within PACs. In 2017 and again in 2020, a memorandum of understanding (MOU) was signed by Sierra Pacific Industries, California Department of Forestry and Fire Protection, National Fish and Wildlife Foundation, and the Forest Service to coordinate on certain actions that may contribute to forest fuel reductions and CSO conservation (see section 4.9). The purpose of the MOU is to try to minimize the threat of large-scale high-severity fire while still providing quality habitat for CSO. However, large-scale high-severity fire cannot be completely addressed by regulatory mechanisms. Fuel reduction treatments may not prevent catastrophic damage in an extreme fire event; however, some studies show that when fire is a part of the fuel reduction treatment, future fire severity can be reduced and more fire treatments should be included to achieve fuels reduction goals, including areas surrounding spotted owl nests and riparian corridors (North et al. 2021, pp. 527, 529; Taylor et al. 2022, p. 4). For more information on measures that address the threat of wildfire, see 4.9 Regulatory Mechanisms and Management Actions.

High severity fire is likely to continue to be a threat into the future for CSO. Though some individuals could be harmed or killed by large fires, the primary impact of this threat is habitat-based. These habitat changes also affect demographic parameters: following high severity fires, colonization declines and territory extinction increases, leading to overall declines in occupancy (Tempel et al. 2022, pp. 13–16). Overall, large-scale high-severity fire is currently and will likely continue to be a threat throughout the range of CSO (Figure 8).

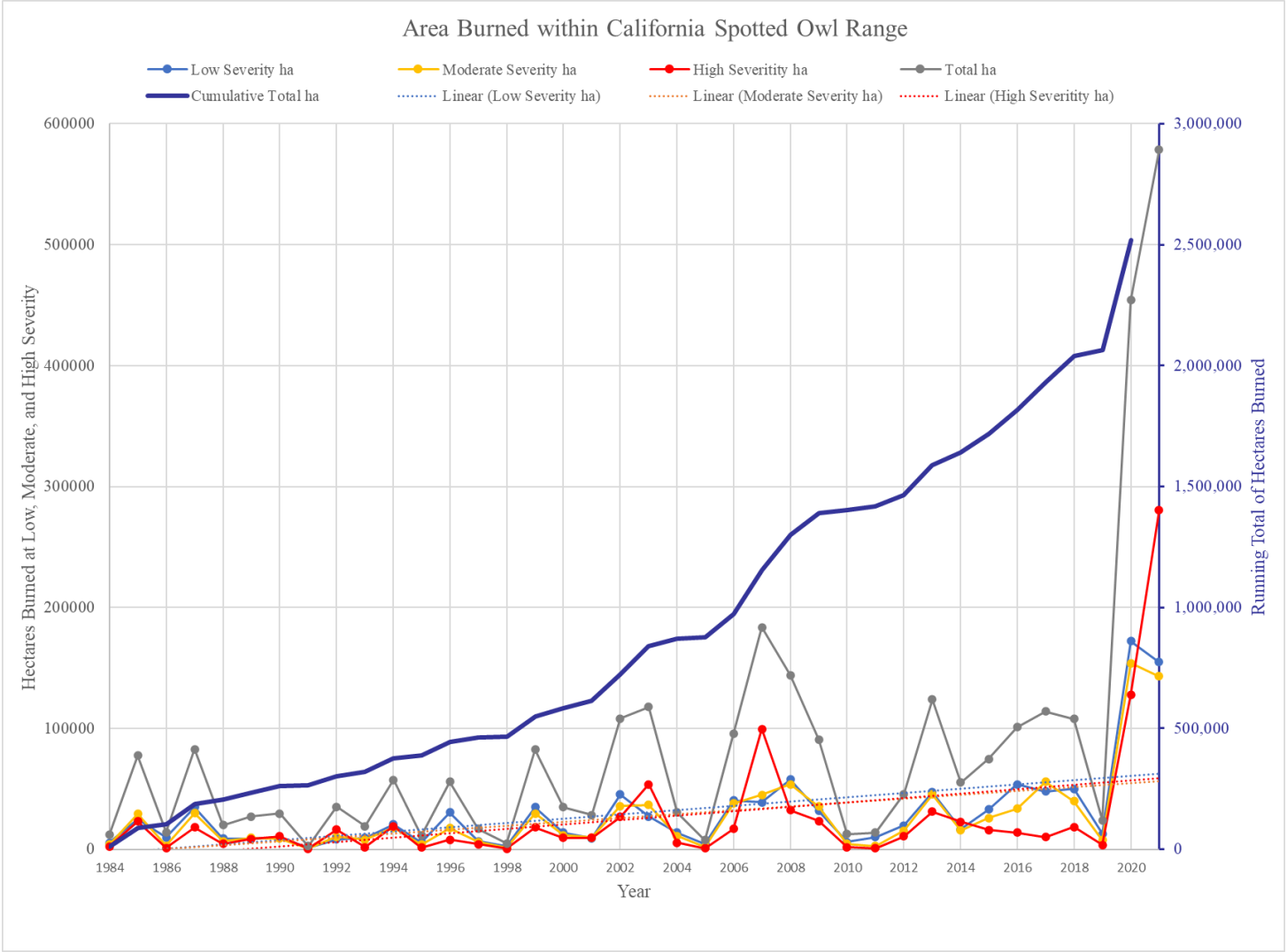


Figure 6: Wildfire area and severity throughout the California spotted owl (CSO) range from 1984–2021. The wildfire severity data from 1984-2020 are from the Monitoring Trends in Burn Severity program (https://mtbs.gov) managed by the U.S. Forest Service Geospatial Technology and Applications Center and the U.S. Geological Survey Center for Earth Resources Observation and Science. We used extended survey assessments (i.e., not immediately postfire) for the fire severity calculations. The data for 2021 fires are from Rapid Assessment of Vegetation Condition after Wildfire (https://burnseverity.cr.usgs.gov/ravg/) managed by the U.S. Forest Service Geospatial Technology and Applications Center to provide a rapid assessment of fire severity based on remotely sensed data. Linear trendlines are displayed for low, moderate, and high severity through time. A running total (with axis on right) displays the running total of area burned within the CSO range.

Wildfire Severity within California Spotted Owl Range

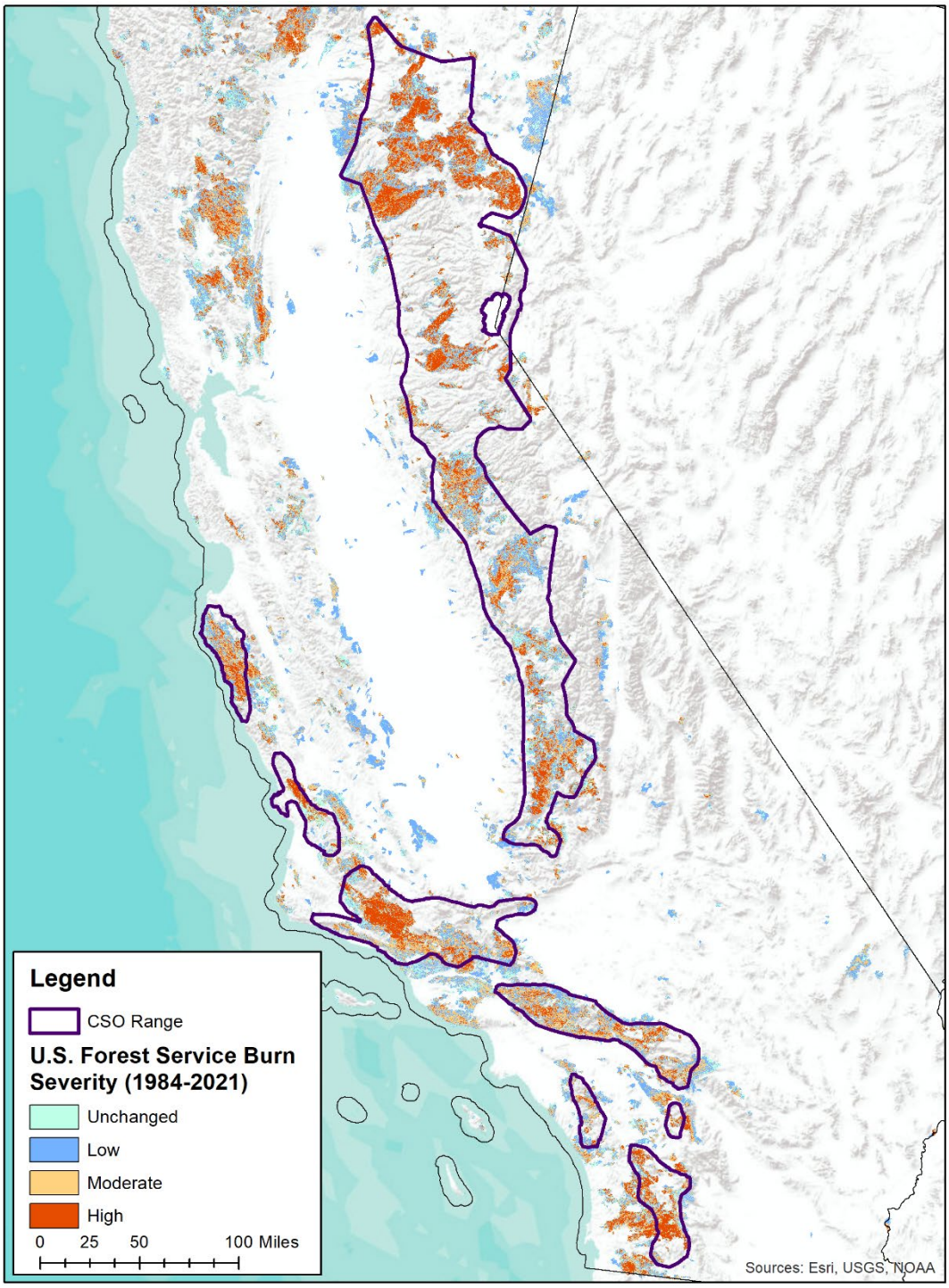


Figure 7: Wildfire location and severity from 1984–2021 within California spotted owl range. The wildfire severity data from 1984-2020 are from the Monitoring Trends in Burn Severity program (https://mtbs.gov) managed by the U.S. Forest Service Geospatial Technology and Applications Center and the U.S. Geological Survey Center for Earth Resources Observation and Science. We used extended survey assessments (i.e., not immediately postfire) to present fire severity. The data for 2021 fires are from Rapid Assessment of Vegetation Condition after Wildfire (https://burnseverity.cr.usgs.gov/ravg/) managed by the U.S. Forest Service Geospatial Technology and Applications Center to provide a rapid assessment of fire severity based on remotely sensed data.

Table 3: Percentage of CSO range burned at low, moderate, and high severity from 1984 to 2021.

Year	Low Severity (ha)	Moderate Severity (ha)	High Severity (ha)	Total (ha)
1984	0%	0%	0%	0%
1985	0%	0%	0%	1%
1986	0%	0%	0%	0%
1987	1%	0%	0%	1%
1988	0%	0%	0%	0%
1989	0%	0%	0%	0%
1990	0%	0%	0%	0%
1991	0%	0%	0%	0%
1992	0%	0%	0%	1%
1993	0%	0%	0%	0%
1994	0%	0%	0%	1%
1995	0%	0%	0%	0%
1996	0%	0%	0%	1%
1997	0%	0%	0%	0%
1998	0%	0%	0%	0%
1999	1%	0%	0%	1%
2000	0%	0%	0%	1%
2001	0%	0%	0%	0%
2002	1%	1%	0%	2%
2003	0%	1%	1%	2%
2004	0%	0%	0%	0%
2005	0%	0%	0%	0%
2006	1%	1%	0%	1%
2007	1%	1%	2%	3%
2008	1%	1%	0%	2%
2009	0%	1%	0%	1%
2010	0%	0%	0%	0%
2011	0%	0%	0%	0%
2012	0%	0%	0%	1%
2013	1%	1%	0%	2%
2014	0%	0%	0%	1%
2015	1%	0%	0%	1%
2016	1%	1%	0%	2%
2017	1%	1%	0%	2%
2018	1%	1%	0%	2%
2019	0%	0%	0%	0%
2020	3%	2%	2%	7%
2021	2%	2%	4%	9%
TOTAL	**17%**	**15%**	**15%**	**47%**

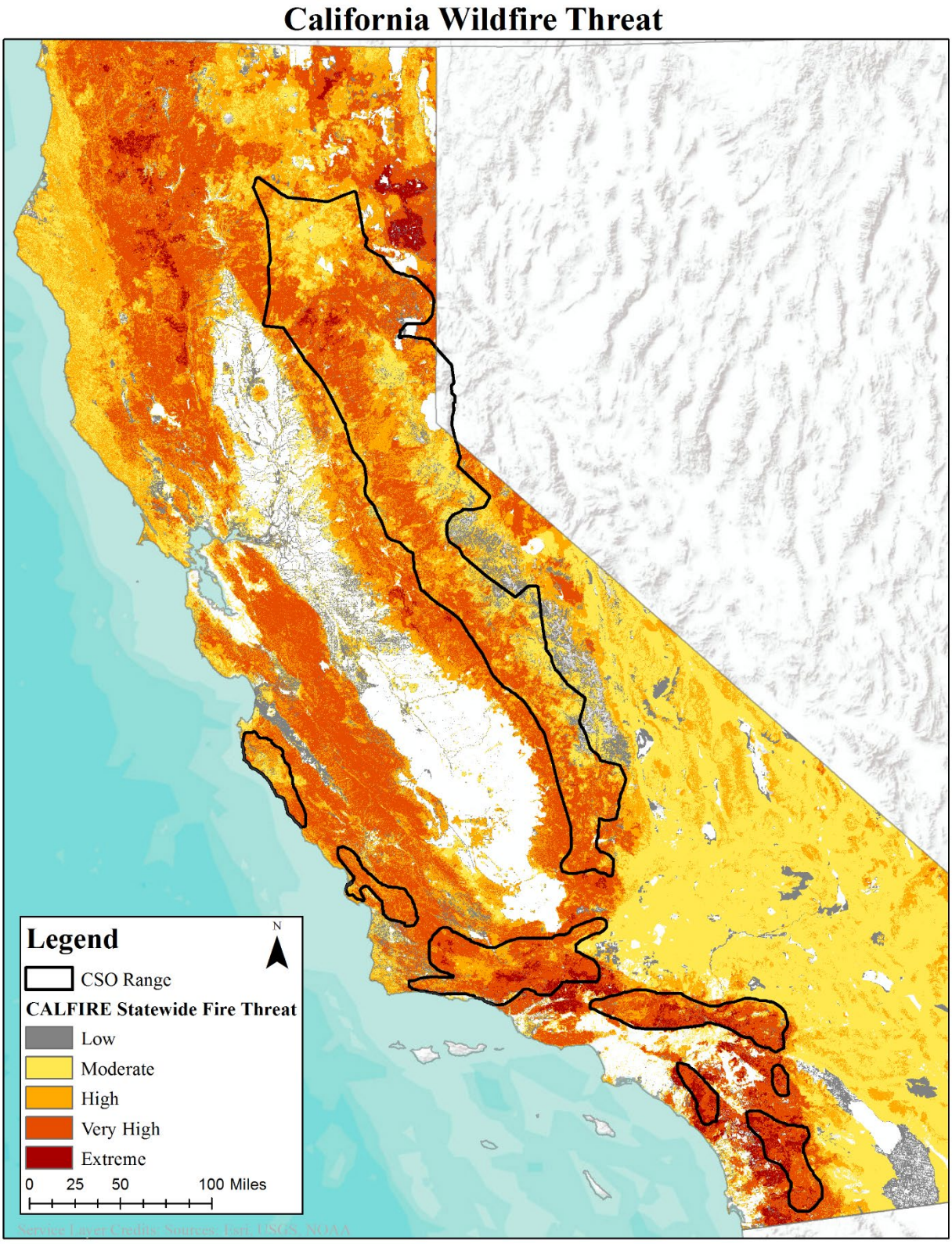


Figure 8: California Department of Forestry and Fire Protection's Fire and Resource Assessment Program statewide wildfire threat map. (https://frap.fire.ca.gov/mapping/gis-data/). Wildfire threat shows the potential of a particular area to burn. These data were developed in collaboration with California Department of Forestry and Fire Protection and Pyrologix Inc. using fuel rank data developed in 2005 with fire rotation data updated through 2014.

4.2 Tree Mortality

Widespread increases in tree mortality have been occurring in California due to drought, disease, and bark beetles, above historical levels of mortality (van Mantgem et al. 2009, pp. 521–523; Asner et al. 2015, p. 249; McIntyre et al. 2015, p. 1458; Preisler et al. 2017, p. 166). Drought conditions combined with dense forest conditions have led to severe water stress throughout California (Asner et al. 2015, p. 249; McIntyre et al. 2015, p. 1459; Young et al. 2017, p. 78). Water stress interacts with pathogens, insects, and air pollution to contribute to tree mortality events (Lutz et al. 2009, pp. 2301–2303; McIntyre et al. 2015, p. 1461; Preisler et al. 2017, p. 166). When tree stand densities are too high compared to available resources (water, light, nutrients), trees become stressed due to competition for resources and thus are more vulnerable to mortality (Forest Service 2017, p. 9). Large trees are often more prone to drought, disease, and beetle-related mortality (Smith et al. 2005, p. 266; Mueller et al. 2005, p. 1085; Allen et al. 2010, p. 668; McIntyre et al. 2015, p. 1458). However, it is difficult to quantify how severe the ongoing effects of tree mortality are on CSO and their ability to find habitat with large trees and multi-layered high canopy cover. To further complicate the quantification of impacts from this stressor, tree mortality events can have some positive effects on CSO habitat as they contribute to habitat heterogeneity and the availability of coarse woody debris for prey species. Increased tree mortality may be contributing to a decrease in CSO habitat (Gutiérrez et al. 2017, p. 137), but the magnitude of the impacts on CSO is uncertain. Large-scale tree mortality reduces the availability of the individual CSO need of multi-layered high canopy cover habitat and large trees, potentially then resulting in population declines because of reduced habitat available for dispersal and occupancy.

Between 2010 and 2016, an estimated 102 million trees died across about 3,106,367 ha (7,676,000 ac) throughout California (TMTF 2017, p. 2). By February 2019, total tree mortality in California increased to an estimated 147 million dead trees (CAL FIRE and Forest Service 2019, p. 1). The latest estimate shows that between 2010 and 2021, the drought combined with subsequent beetle attacks resulted in approximately 173 million dead trees in California (Forest Service 2021, p. 5). The tree mortality events are particularly severe in the southern Sierra Nevada area. Most of the tree mortality observed is due to effects from the 2012–2016 drought with less mortality occurring from 2018-2021; however, another drought period started in 2020 (Forest Service 2021, p. 5). Figure 9 presents the Forest Service's 2017 tree mortality survey and shows dead trees per acre within the CSO range. We are not aware of tree mortality survey information from 2020 or 2022.

In 2015, the California Governor declared a state of emergency due to the unprecedented number of dead and dying trees in the state. In response, the California Tree Mortality Task Force, which is now the Forest Mortality Working Group within the California Wildfire and Forest Resilience Task Force, was created to coordinate emergency protective actions and monitor ongoing conditions. The group collects and manages the tree mortality data, provides recommendations to land managers, presents grants for research funding, and provides public outreach. The task force will likely continue to provide the services listed into the future due to the ongoing and large-scale nature of the tree mortality events in California. The threats that are driving the tree mortality events (drought, disease, and bark beetles) are difficult to manage; therefore, most of the on the ground recommendations involve preventing large-scale high-severity fires, ensuring public health, and

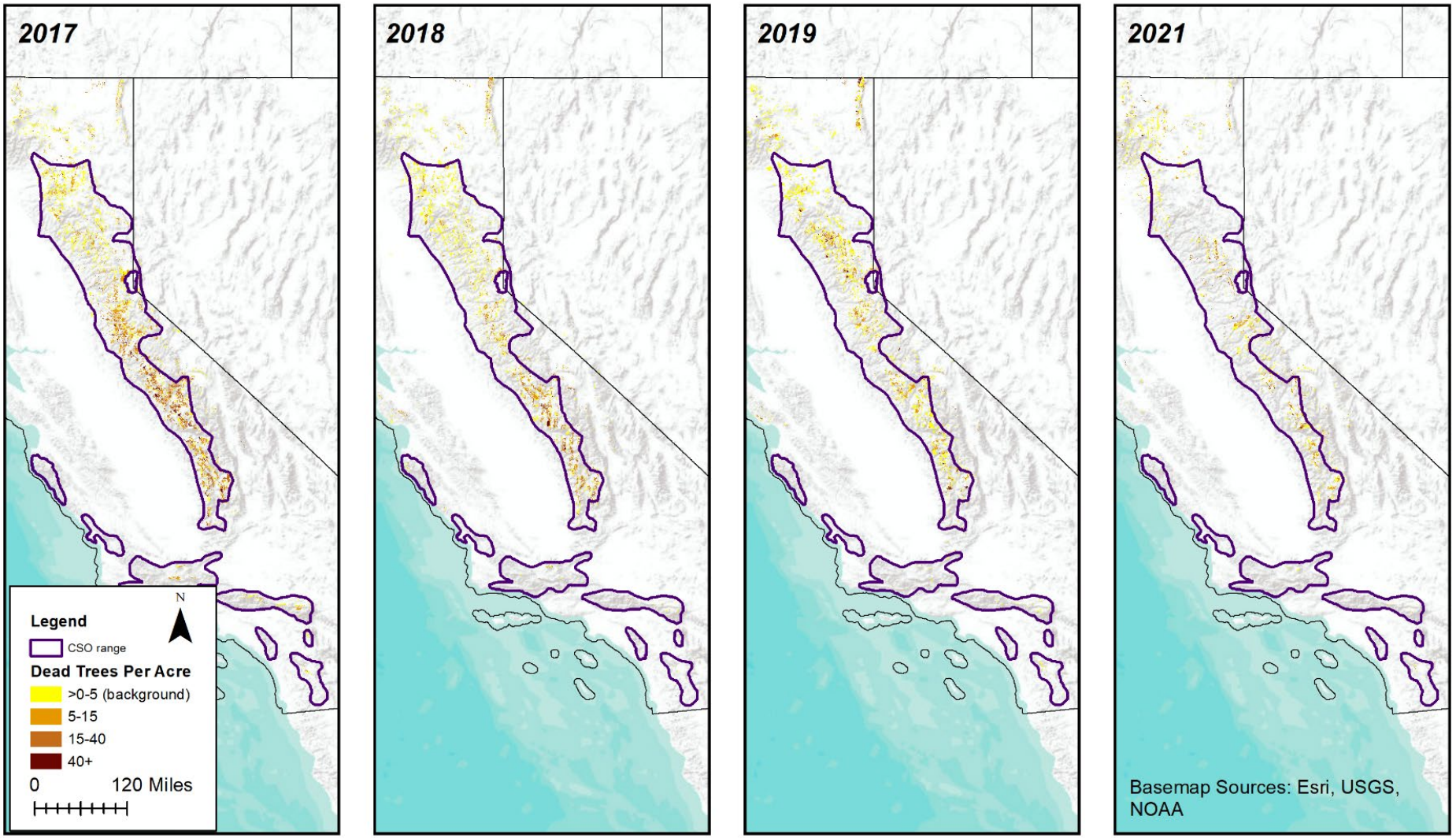


Figure 9: Map portraying tree mortality within California spotted owl range per year. Tree mortality data are from the U.S. Forest Service Tree Mortality Survey 2017-2021 (Forest Service 2021). Data were not available for 2020.

strategizing resilient reforestation. More information about the California Wildfire and Forest Resilience Task Force and their efforts can be found at https://wildfiretaskforce.org/ (also see Prescribed Fire in section 4.5 Fuels Reductions and Forest Management).

Some regulatory mechanisms and management actions could provide some protection from the effects of tree mortality. Efforts to restore historical forest conditions and reduce stand densities through fuels reduction treatments (mechanical thinning, prescribed fire, etc.) may indirectly contribute to reducing future tree mortality by reducing competition, though these activities cannot completely eliminate future tree mortality. Further, the goal should be to eliminate the excessive levels of tree mortality currently being observed in the landscape and not limit all tree mortality, as tree mortality is a natural part of the forest ecosystem and ultimately creates features important to CSO (snags, tree cavities, etc.). Tree mortality is likely to continue throughout the range of CSO due to predicted increases in drought conditions that will likely continue to weaken trees and make them susceptible to bark beetles and disease (Millar and Stephenson 2015, pp. 823–826; Young et al. 2017, pp. 78, 85). Excessive tree mortality is likely to continue to be a threat into the future for CSO.

4.3 Drought

California has recently experienced extreme drought conditions in 2007–2009, 2012–2016 (Williams et al. 2015, pp. 6823–6824; California Department of Water Resources 2021, p. 4), and as of May 2022 a majority of the CSO's range is considered in severe to moderate drought (CDWR 2022, https://cww.water.ca.gov/). Anthropogenic warming likely contributed to more recent drought anomalies and increases the overall likelihood of extreme droughts in California into the future (Williams et al. 2015, pp. 6819, 6826); CDWR 2022, https://cww.water.ca.gov/; see 4.4 Climate Change).

Drought conditions can negatively impact the species ecological needs. As described above, drought conditions contribute to tree mortality, which reduces the CSO habitat component of multi-layered high canopy cover, likely leading to a decline in occupancy. Further, it is likely that drought conditions reduce the availability of prey species (Franklin et al. 2000, p. 589; Glenn et al. 2010, p. 2549, 2011, p. 174). Drought and hot temperatures in the previous summer are linked to lower reproductive success in CSO (LaHaye et al. 2004, p. 1066) and lower survival and recruitment in northern spotted owls in the next breeding season (Glenn et al. 2011, pp. 159, 174). Inversely, increases in precipitation either before or after the nesting season are linked to increased survival and fecundity in all three subspecies of spotted owls (Seamans et al. 2002, p. 321; LaHaye et al. 2004, pp. 1056, 1064; Glenn et al. 2011, pp. 159, 174). Thus, drought likely negatively impacts CSO habitat components, and demographic needs of dispersal, survival, fecundity, and occupancy. There are no regulatory mechanisms or conservation measures in place to ameliorate the direct impacts of drought to CSO. It is likely that drought conditions will continue to be a threat into the future across the CSO range, and will likely worsen, due to the effects of climate change.

4.4 Climate Change

Our analyses include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather

conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2013a, p. 1450). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (for example, temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2013a, p. 1450).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring and that the rate of change has been faster since the 1950s. Examples include warming of the global climate system, substantial increases in precipitation in some regions of the world, and decreases in other regions (for these and other examples, see (Solomon et al. 2007, pp. 35–54, 82–85; IPCC 2013a, pp. 3–29, 2014, pp. 2–8). The IPCC characterizes warming of the global climate system as "unequivocal" (IPCC 2013b, p. 2), and reports that human influence has been detected in warming of the atmosphere and ocean, changes in the global water cycle, reductions in snow and ice, global mean sea level rise, and changes in some climate extremes (IPCC 2013b, pp. 15, 17, Figure SPM.6, Tabel SPM.1). Results of scientific analyses presented by IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "extremely likely" (defined by the IPCC as 95% or higher probability) that this change is due to the observed increase in greenhouse gas concentrations in the atmosphere as a result of human activities (Solomon et al. 2007, pp. 21–35; IPCC 2013b, pp. 2, 15, Figures SPM.4, SPM.5, SPM.6).

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of greenhouse gas emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl et al. 2007, p. entire; Ganguly et al. 2009, pp. 15555, 15558; Prinn et al. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that greenhouse gas emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of greenhouse gas emissions (Meehl et al. 2007, pp. 760–764, 797–811; Ganguly et al. 2009, pp. 15555–15558; Prinn et al. 2011, pp. 527, 529; IPCC 2013b, pp. 19–23). See IPCC 2013b (entire), for a summary of other global projections of climate-related changes, such as frequency of heat waves and changes in precipitation.

Climate projections at the global scale are informative, and, in some cases, the only scientific information available for us to use. However, projected changes in climate and related impacts can vary substantially across and within different regions of the world (IPCC 2013b, pp. 15–16). Therefore, we use "down-scaled" projections when they are available and have been developed through appropriate scientific procedures, because such projections provide higher resolution information that is more relevant to spatial scales used in the analyses of a given species (see (Glick et al. 2011, pp. 58–61) for a discussion of downscaling).

Downscaled climate projections were completed for different regions of California for California's Fourth Climate Change Assessment, including the following four regional assessments that cover the range of CSO: Sierra Nevada (Dettinger et al. 2018, p. entire), Central Coast (Langridge 2018, p. entire), Los Angeles (Hall et al. 2018, p. entire), and San Diego (Kalansky et al. 2018, p. entire). Ten global climate models were used for all four regional assessments and each model considered two different emissions scenarios, one in which greenhouse gas emissions continue to increase into the next century (RCP 8.5) and one in which greenhouse gas emissions stabilize by mid-century and then decline to levels seen in the 1990s by the end of the century (RCP 4.5) (Dettinger et al. 2018, pp. 15, 17; Hall et al. 2018, p. 9; Kalansky et al. 2018, p. 18; Langridge 2018, p. 12).

Under both emissions scenarios, projected annual average temperatures throughout the CSO range are projected to increase. Annual average temperatures in the Sierra Nevada Region, which includes the entire Sierra Nevada Mountain Range, are projected to increase approximately 4–5ºF by mid-century (2036–2065) and 5–7ºF by the end of the century (2070–2099) under RCP 4.5, and 6ºF by mid-century and 9–10ºF by the end of the century under RCP 8.5 (Dettinger et al. 2018, pp. 15, 17, Figure 2.1). The largest increases under both emissions scenarios and timeframes are projected for the eastern portions of the Sierra Nevada (Dettinger et al. 2018, pp. 17, Figure 2.3). Projected changes will result in greater temperatures than historically experienced in the Sierra Nevada and this degree of temperature change will likely result in a shift in the rain to snow transition by 1,500–3,000 feet (Dettinger et al. 2018, pp. 17, 20).

Throughout the Central Coast Region, which includes portions of San Benito, Santa Cruz, San Luis Obispo, Monterey, Santa Barbara, and a small portion of northern Ventura counties, projected annual average maximum and minimum temperatures are expected to increase under both emissions scenarios. The annual average maximum temperature under RCP 4.5 is projected to increase 3.5–4.5ºF by mid-century (2040–2069) and 4.5–5.5ºF by the end of the century (2070–2099), with increases under RCP 8.5 at 4.5–5.5ºF by mid-century and 7–8ºF by the end of the century, (Langridge 2018, pp. 13, Table 2). Annual average minimum temperatures are expected to increase 3.5–4.5ºF by mid-century and 4.5–5ºF by the end of the century under RCP 4.5, and 4.5–5ºF by mid-century and 7–8ºF by the end of the century under RCP 8.5 (Langridge 2018, pp. 14, Table 3). Projected temperature increases are more pronounced in the inland portions of the Central Coast Region with the ocean acting as a buffer for coastal areas (Langridge 2018, pp. 14, Figure 4). In addition, the average number of extremely hot days (defined as days that exceed the 98th percentile of observed, historical (1961-1990) daily maximum temperatures between April 1 and October 31) are expected to increase throughout the Central Coast Region, with counties in the CSO range projected to experience between approximately 2 and 4.5 times as many extremely hot days under RCP 4.5 and between 2.5 and 6.5 times as many extremely hot days under RCP 8.5 by mid-century (historical average number of days is 4.3). By the end of the century, the number increases to 4 to 6 times as many extremely hot days under RCP 4.5 and between 7.5 and 11.5 times as many extremely hot days under RCP 8.5 (Langridge 2018, pp. 14–15, Table 4).

Regional assessments covering southern California include the Los Angeles Region, which includes Ventura, Los Angeles, Orange and portions of San Bernardino and Riverside counties, and the San Diego Region, which covers San Diego County (Hall et al. 2018, p. entire; Kalansky et al.

2018, p. entire). Projected annual average maximum temperatures throughout the Los Angeles Region increase under both emissions scenarios, with increases of 4.2°F by mid-century (2040-2069) and 5.3°F by the end of the century (2070–2100) under RCP 4.5 and increases of 5.7°F and 8.4°F by mid-century and end of the century under RCP 8.5, respectively (Hall et al. 2018, pp. 10, Figure 2).

For the San Diego Region, projected annual average maximum and minimum temperatures increase under both emissions scenarios. By mid-century (2040–2069), annual average maximum and minimum temperatures are projected to increase by approximately 4–5ºF and 5–6ºF under RCP 4.5 and RCP 8.5, respectively. By the end of the century (2070–2100), the annual average maximum and minimum temperatures under RCP 4.5 are projected to increase 4–6ºF, with increases under RCP 8.5 at 7–9ºF (Kalansky et al. 2018, pp. 19, Figures 2 and 3). In addition, by the end of the century the average hottest day is projected to increase 4–7°F under RCP 4.5 and 7–10°F under RCP 8.5 for both southern California climate change assessment regions (Hall et al. 2018, pp. 11, Figure 4; Kalansky et al. 2018, pp. 21, Figure 6). Similar to the Central Coast, these changes will be more pronounced in the interior portions of the Los Angeles and San Diego Regions (Hall et al. 2018, pp. 11, Figure 3).

In addition to temperature projections, the regional assessments for California's Fourth Climate Change Assessment also considered future changes in precipitation, both the amount and the timing. Within the Sierra Nevada Region, changes in precipitation are projected to be relatively small and will vary depending on the area. In general, average annual precipitation in the southern portion of the Sierra Nevada Region is projected to stay similar or decrease by 5%, regardless of emission scenario. In other portions of the Sierra Nevada Region, particularly along the eastern side, the amount of precipitation is projected to increase by up to 10%. In addition to projections showing northern portions of the range will receive more precipitation than southern portions, areas at higher elevations are also more likely to receive an increase in precipitation. One area in eastern Plumas County at approximately 6,000 feet elevation, just south of Honey Lake, has projected increases of 25% under RCP 8.5 (Dettinger et al. 2018, pp. 5, 18, 20, Figure 2.1); however, this larger projected change is in a very small area relative to the rest of the Sierra Nevada Region. Although the average change in precipitation is projected to be small, the models show there will be an increase in extreme conditions with more dry days overall interspersed with higher intensity precipitation events, when they do occur (Dettinger et al. 2018, p. 19). Further, in some areas more precipitation will fall as rain instead of snow as the rain to snow transition is projected to shift by 1,500–3,000 feet (Dettinger et al. 2018, pp. 17, 20).

Similar to the Sierra Nevada Region, interannual variability within the Central Coast Region is expected to increase with more dry days overall, but more precipitation when rain events do occur (Langridge 2018, p. 16). Under RCP 4.5, average annual precipitation is expected to increase 1–2 inches under both time periods (i.e., mid-century and end of century) in Monterey, San Luis Obispo, and Santa Barbara counties, the three counties in which the species occurs (Langridge 2018, pp. 16, Table 6). Under RCP 8.5, average annual precipitation is expected to increase by 1.5–2 inches by mid-century and by 4–5 inches in those same counties by the end of the century (Langridge 2018, pp. 16, Table 6).

In southern California, the amount of precipitation in the Los Angeles and San Diego Regions is highly variable (Hall et al. 2018, pp. 12, Figure 5; Kalansky et al. 2018, p. 24). Projections for the Los Angeles Region do not agree whether changes will be negative or positive, likely because the Los Angeles Region lies between an area that is projected to be wetter (northern mid-latitude) and an area projected to be drier (southern sub-tropics), although there is agreement the overall changes will be small (Hall et al. 2018, p. 13). Similar to other regions, projections for the Los Angeles and San Diego Regions show an increase in extreme conditions such as high intensity precipitation events, known as atmospheric rivers, and severe drought conditions (Hall et al. 2018, pp. 13–14, Figure 6; Kalansky et al. 2018, pp. 24–25, Figures 7 and 9).

Because CSO has such a wide geographic range and the changes in climate vary across the range, the effects those changes will have on the species and its habitat will vary. Future climate projections of Sierra Nevada vegetation distribution indicate that low- and mid-elevation forests are vulnerable to conversion to unsuitable habitat for CSO, such as shrublands and grasslands (Gutiérrez et al. 2017, p. 215). These changes in climate may also include potential shifts in forest communities upslope, which would have impacts on both CSO habitat and prey habitat (Gutiérrez et al. 2017, pp. 132, 215, 288). This potential upslope shift in suitable habitat may mitigate some climate-induced habitat threats over ecological time, although it would require many decades for suitable large nest trees to develop in areas where they do not currently exist (Gutiérrez et al. 2017, p. 215). These differences in net habitat loss versus net habitat gained under future climate scenarios will likely depend upon not only the rate of warming but also how individual plant and prey species respond (Seamans and Gutiérrez 2007a, p. 61).

Changing climatic conditions may have direct impacts on CSO physiology, survival, reproduction, recruitment, or population growth. The thermal neutral zone (i.e., the range of temperatures tolerated by a warm blooded animal) for CSO is 18.2–35.2 degrees Celsius (64.8–95.4 degrees Fahrenheit) (Weathers et al. 2001, p. 682). Above the thermal neutral zone, CSO experience heat stress which negatively affects the physiology of an individual (Weathers et al. 2001, p. 678). The relatively low thermal neutral zone may make CSO more susceptible to increased temperatures or cause behavioral or habitat shifts to cooler microclimates on the landscape. Behaviorally, CSO do show the capacity to select cooler microclimates for roosting, especially within warmer forest stands (McGinn et al. in review, p. 2). Changing climatic conditions may also have indirect impacts including changes in habitat and prey distribution, abundance, and quality. CSO must be able to adjust to the changing climate through behavioral changes, spatial shifts, or adaptation in order to persist. Under projected warming conditions in the future, cooler microclimate refugia are likely to be critically important for the persistence of CSO individuals and populations (McGinn et al. in review, p. 3). It is likely that climate change will reduce the quantity and quality of CSO habitat, which would likely result in population impacts including a decrease in dispersal, fecundity, and occupancy. Both the habitat components and demographic factors of CSO will likely be impacted by climate change, but the full extent of impacts climate change may have on CSO are poorly understood (Wan et al. 2018, p. 690).

Climate modeling specific to the central Sierra Nevada portion of the CSO range has shown that maintaining high canopy cover, especially at higher elevations, will be important for CSO to persist into the future as it helps maintain future refugia for individuals to select for cooler

microclimates (Jones et al. 2016b, entire). (Jones et al. 2016b, p. 901) shows the change in CSO occupancy probability for different climate change scenarios with different forest management strategies for canopy cover. Under both a low climate change prediction scenario (RCP 2.6) and a high climate change scenario (RCP 8.5), CSO occupancy decreases in comparison to baseline climate conditions (Jones et al. 2016b, p. 901). However, it is important to note that this model did not consider projected increases in frequency and size of high-severity fires due to climate change, which would likely result in more significant declines in occupancy than predicted by the model (Jones et al. 2016b, p. 903). Earlier modeling of spotted owl response to projected climate changes show that different subspecies and populations of spotted owls are anticipated to respond differently across the species range (Peery et al. 2011, p. 14).

The climate change projections described above suggest increasing interannual climate variability throughout the range of CSO. Interannual climate variability is defined as when annual weather patterns differ from historical average climate, including prolonged drought conditions, heavy rain conditions, and higher or lower than average temperatures. Interannual climate variability has been shown to have impacts on the survival and reproductive success of CSO. Drought conditions and hot temperatures during the summer have been found to reduce fecundity the next breeding season in CSO (LaHaye et al. 2004, p. 1056). Increases in precipitation either before or after the nesting season are linked to increased survival and fecundity, whereas increased precipitation during the nesting season reduces reproductive success (North et al. 2000, p. 804; LaHaye et al. 2004, pp. 1056, 1064). It is hypothesized that northern spotted owls exhibit a bet-hedging reproduction strategy and an absence of reproduction is linked to environmental conditions (Franklin et al. 2000, pp. 539, 576). California spotted owls likely have a similar bet-hedging reproductive strategy (Stoelting et al. 2015, p. 46; Gutiérrez et al. 2017, pp. 14–15). California spotted owls are sensitive to warm temperatures and therefore may be physiologically sensitive to weather patterns with increased temperatures (Weathers et al. 2001, p. 684). Temperature, either too hot or too cold, may affect spotted owls directly by increasing energy demands (Gutiérrez et al. 2017, p. 20). This may have direct impacts on the physiology of spotted owls or on breeding if mates must bring more food to the nest for the female to survive. Increased interannual climate variability due to climate change will likely impact CSO throughout the range, which would result in lower fecundity.

Regulatory mechanisms and management actions that are or could potentially provide some protection from the effects of climate change include the Clean Air Act and the California Global Warming Solutions Act. Both address climate change by reducing greenhouse gas emissions within the United States and California, respectively. There are no regulatory mechanisms or management actions that fully address the effects of the climate change. For more information on the Clean Air Act and the California Global Warming Solutions Act, see 4.9 Regulatory Mechanisms and Management Actions.

The effects of climate change will continue to impact CSO into the future by exacerbating the negative influencing factors described above, especially extreme weather events such as prolonged drought and severe storms. The loss and/or reduction of suitable habitat throughout the CSO range and will likely reduce reproduction, occupancy, survival, recruitment, and population growth.

4.5 Fuels Reductions and Forest Management

Forest management has long been a controversial topic regarding species that require old growth forest habitat, including the spotted owl (Gutiérrez 2020, p. 337). With the increasing frequency and extent of high-severity fire in California in recent decades, the focus on fire mitigation has become a key issue for spotted owl management and conservation. While spotted owls are adapted to a natural fire regime (Verner et al. 1992, pp. 247–248; Stephens et al. 2019, p. 394), CSO are poorly adapted to the conditions created by large-scale high-severity fires (Jones et al. 2020b, 2021b, p. 5) that have negative effects on both CSO and their habitat (see section 4.1 Wildfire, above). The goal of fuels management is to reduce the buildup of fuels in forests that contribute to these large-scale high-severity fires, which can effectively mitigate subsequent fire behavior and their effects, even under extreme weather (Hessburg et al. 2021, p. 7; Prichard et al. 2021, p. 9). Fuels management may also help bring treated areas closer to the natural range of variation of forest structure and fire severity (Tubbesing et al. 2019, p. 52). Modeling suggests that the long-term benefits of properly managed fuel treatments for reducing the risk of severe wildfire are likely to outweigh the short-term negative impacts to spotted owl habitat (Ager et al. 2007, pp. 54–55; Roloff et al. 2012, p. 7; Jones et al. 2021a, pp. 4–5). These trade-offs are complex and ultimately depend on the extent that treatments alter owl habitat and the magnitude of effects from subsequent wildfires (Jones et al. 2021a, p. 2). Fuels reductions and forest management practices vary throughout the CSO range. In this section we discuss clearcutting, mechanical thinning, salvage logging, and prescribed fire, and the positive and negative influences that these practices can have on the species.

Clearcutting

Clearcutting, sometimes referred to as even-aged management, is defined as an even-age regeneration or harvest method that removes all trees in the stand, producing a fully exposed microclimate for the development of a new age class in one entry (Gutiérrez et al. 2017, p. 292). The natural range of variation for forest gaps in the Sierra Nevada has been found to range from 0.03–1.17 ha (0.07–2.89 ac) (Safford and Stevens 2017, p. 140), and within this SSA Report, clearcutting refers to complete removal greater than the natural range of variation.

Clearcutting is a mostly historical threat to CSO, although it still occurs in some areas of the Sierra Nevada portion of the range. By removing entire stands of trees, clearcutting reduces the amount of large trees, high canopy cover, and coarse woody debris available for CSO. Commercial timber harvest no longer occurs within CSO range in southern California on public lands (Gutiérrez et al. 2017, p. 254). Clearcutting also does not occur on National Forest Service lands on the eastern side of the Sierra Nevada range (Boatner in litt 2018.). Clearcutting prescriptions were incorporated into forest management on Forest Service lands within the CSO range in the 1970s and continued up until the 1990s (Gutiérrez et al. 2017, p. 111). Clearcutting over this time period likely reduced the amount of available CSO habitat. Since the release of the 1992 "California Spotted Owl: Technical Assessment of Its Current State" report (Verner et al. 1992), clearcutting has significantly decreased to a minimal amount on Forest Service land (Gutiérrez et al. 2017, pp. 111–117). Clearcutting still occurs on private timber harvest lands but is limited to 8.1-ha (20-ac) parcels by California state forest practice rules (14 CCR 913). Additionally, there must be at least 91.44 m (300 ft) of forested area between clearcuts, and adjacent lands cannot be cut for at least 5 years (14 CCR 913). Even with the reduction of clearcutting in recent history, it will take decades or centuries for

large trees to grow back from the past removal practices; therefore, there are residual effects that may be impacting CSO populations and the habitat that is available (Jones et al. 2018, p. 1). There is evidence that CSO may use clearcut habitat, likely for foraging activities, but these areas were used significantly less than high canopy cover and large tree areas (Atuo et al. 2019, pp. 295, 301–302). Further, there is evidence of negative impacts from clearcutting to northern spotted owl, including decreased dispersal and decreased use of clearcut areas (Forsman 1980, pp. 4, 52–53, 83–85; Forsman et al. 1984, pp. 25, 54; Carey et al. 1990, p. 11; Bart and Forsman 1992, p. 95; Miller et al. 1997, pp. 140, 145–148).

Mechanical Thinning

Mechanical thinning is a forest management strategy to thin trees either in even or uneven-aged stands by removing trees in rows, strips, or by using fixed pacing intervals, usually implemented to meet forest management objectives. It can be done for commercial harvest of trees or to reduce fuel loads to decrease the likelihood of large-scale high-severity fires (Gutiérrez et al. 2017, p. 292). Within this SSA Report, we use "mechanical thinning" to include both individual tree selection (new age classes are created in uneven-aged stands by removing individual trees of all size classes more or less uniformly throughout the stand to achieve desired stand structure) and group tree selection (treatment involves salvage harvest in a stand where small groups of trees are harvested because of tree mortality due to windstorm, wildfire, insects, disease, or other animals). Mechanical thinning can occur from below, where trees are removed from the lower canopy leaving large trees to occupy the site, or from above (crown thinning), which reduces crowding within the main canopy.

Mechanical thinning is actively used to manage forests occupied by CSO and can have positive or negative impacts on CSO habitat and demographics depending on the specific methods used. The Forest Service's 2004 Sierra Nevada Forest Plan Amendment promotes reducing unnaturally dense forest conditions on the landscape to reduce the risk of large-scale high-severity fire, which can involve mechanical thinning (Forest Service 2004, pp. 34–35) (see 4.9 Regulatory Mechanisms and Management Actions for more information on Forest Plans). Minimal area is treated mechanically, especially when compared to area burned by wildfire (i.e., 1.4 million acres burned between 2017-2020 versus 152,842 acres previously treated; North et al. 2021, p. 524). Treatments are located to avoid CSO activity centers to the greatest extent possible (Forest Service 2004, pp. 34–35), which often leaves the PACs untreated and potentially vulnerable to stand-replacing fires (Stephens et al. 2019, p. 395). Further, researchers recommend that strategic thinning can promote forest resiliency, but removing some large, fire-intolerant tree species like fir and cedar may be necessary to promote future resilience of forested habitat (Stephens et al. 2020, p. entire; North et al. 2021, p. 530). Resilience of CSO habitat results from low stand densities, which reduces competition and allows trees to grow, so more intensive fuels treatments (mechanical thinning and prescribed fire) may be needed to achieve historically lower levels of tree densities (North et al. 2022, p. 6). When conducted outside CSO activity centers, mechanical thinning will likely reduce the amount of damage their habitat may experience due to high-severity fire while also minimizing short-term habitat impacts (Stephens et al. 2014, p. 904; Tempel et al. 2015, p. 1; Chiono et al. 2017, p. 1). Strategic mechanical thinning to reduce fuel loads and reduce the risk of large-scale high-severity fire, while also maintaining the necessary forest structure components of large trees, multi-layered high canopy cover, forest heterogeneity, and coarse woody debris, will be important for CSO

management into the future (Jones et al. 2016a, p. 305, 2019, p. 22; Tempel et al. 2016, p. 305). Strategically placed landscape fuel treatments can decrease future fire severity while also increasing seedling densities (Tubbesing et al. 2019, p. 54). Many studies emphasize the importance of scaling up fuel reduction treatments (mechanical thinning and prescribed fire) and suggest an increased benefit of treating within CSO territories for long-term persistence, though positive effects would not be observed until mid-century and treatments should still strive to maintain large trees and high canopy cover forest (Jones et al. 2021a, p. 3; Safford et al. 2022, p. 17).

This fuels management technique has little to no impact on occupancy if carried out in a strategic way; for example, maintaining some patches of high canopy cover mixed with patches of moderate canopy cover to provide for the primary habitat of CSO and incorporating limited operating periods that restricts activities from occurring during the critical nesting period (Tempel et al. 2016, p. 747). However, other studies have found that mechanical thinning can decrease CSO occupancy and is negatively correlated with reproduction (Tempel et al. 2014a, p. 2089, 2022, p. 19; Stephens et al. 2014, p. 903). Though Tempel et al. (2022, p. 22) detected some negative effects of fuels reduction treatments on CSO in southern California, they posit that occupancy declines were small compared to the potential negative effects of fire. Similarly, there is evidence of reduced foraging in fuel treatment areas that have a moderate to high proportion of forest gaps with little to no canopy cover (Gallagher et al. 2018, pp. 487, 494–499). Forest thinning has complex effects on both CSO and their mammalian prey species. Thinning may have negative short-term effects on prey species by increasing the risk of predation by removing above-ground cover, reducing canopy connectivity, and by removing suitable nesting substrates; however, there may be positive effects in the long-term (over decades) by promoting growth of the midstory layer of trees that is favorable to certain mammalian prey species (Wilson and Forsman 2013, p. 79).

Salvage Logging

Salvage logging is a practice where damaged or dying trees are removed to recover their economic value and promote forest health (Gutiérrez et al. 2017, p. 293; Jones et al. 2020a, p. 11). Salvage logging often occurs after natural disturbances such as wildfires, disease, and insect infestation (Lindenmayer et al. 2008, p. 4). Post-fire fuels treatment that includes the removal of smaller trees and surface and ladder fuels is not generally considered a threat to CSO relative to the threat posed by megafires (Jones et al. 2021a, p. 7). Negative effects of salvage logging have been documented for wildlife, vegetation, and soils but there is a paucity of literature which may lead to inaccurate comparisons when studies occur across varied geographic regions; nevertheless, the negative effects may be mediated by altering equipment, timing of operations, and harvest prescriptions to leave more large snags (Nemens et al. 2019, p. entire). California spotted owls have been found to inhabit areas of low-medium severity fire, patchy high-severity fire, and areas with dead trees; therefore, salvage logging likely reduces the amount of habitat available for CSO (Gutiérrez et al. 2017, p. 276). Salvage logging can result in short term decreased vegetation regrowth (Wagenbrenner et al. 2015, p. 176), which would likely impact prey species for CSO. However, salvage logging does not appear to make much difference in long term vegetation regrowth, so salvage logged areas have the potential to again become suitable habitat after the centuries it takes to establish large trees in the area (Peterson and Dodson 2016, p. 56). Salvage logging in certain instances may also be necessary to reduce future fire severity as high levels of dead

biomass were associated with high severity fire (Lydersen et al. 2019, p. 7; Stephens et al. 2022, p. 8) and for restoration personnel to safely access an impacted site for re-planting activities (Sawyer in litt. 2022).

California spotted owl response to salvage logging appears to be at least partly dependent on the characteristics of the fire after which it occurs, which can make it difficult to analyze these relationships (detailed in (Jones et al. 2019). For example, salvage logging that occurs within a large, burned area is less likely to negatively impact spotted owls relative to salvage logging that occurs within a smaller burned area (Jones et al. 2020a, p. 12). There is some evidence that northern spotted owl (Clark et al. 2012, p. 15) and CSO occupancy decreases with salvage logging (Lee et al. 2013, p. 1327; Lee and Bond 2015, p. 228; Hanson and Chi 2021), while other evidence suggests that salvage logging has no effect on CSO persistence or colonization (Jones et al. 2021a, p. 5). Salvage logging can be a threat to CSO when their habitat components of large trees, coarse woody debris, and forest heterogeneity are removed from the landscape, resulting in a decrease in occupancy at the population level. The Forest Service's 2004 Sierra Nevada Forest Plan Amendment prohibits salvage harvest in CSO PACs unless a biological evaluation determines that the areas proposed for harvest have been rendered unsuitable for the purpose they were intended (i.e., CSO habitat) by a catastrophic stand-replacing event (Forest Service 2004, pp. 52–53) (see 4.9 Regulatory Mechanisms and Management Actions for more information on Forest Plans).

Prescribed Fire

Prescribed fire or cultural burning as a tool for ecosystem management had been used for millennia by Native Americans prior to the colonization of North America by Europeans who introduced a culture of fire suppression onto the landscape (Marks-Block et al. 2021, p. 3). Wildfire suppression is still the dominant management practice over prescribed or controlled burning across much of western North America (Stephens et al. 2019, p. 391). Between 2017 and 2020, approximately 120,000 acres per year were treated with prescribed burning across federal, state, and tribal lands in California (Gabbert 2022, p. entire). The state of California recently released a report outlining a plan to increase the use of "beneficial fire" to 400,000 acres annually by 2025 (California Wildfire and Forest Resilience Task Force 2022, p. 3). Spotted owls can persist in low- and moderate-severity fire areas with similar probabilities to unburned landscapes (Roberts et al. 2011, p. 617), demonstrating their adaptation to a natural fire regime (Verner et al. 1992, pp. 247–248; Stephens et al. 2019, p. 394). However, studying the relationship between spotted owls and prescribed fire alone is difficult because there are usually confounding factors of past timber harvest and/or salvage logging (Clark et al. 2012, p. 15). Prescribed "ecologically beneficial" fire is an important tool protecting nesting and roosting habitat from catastrophic fires and for maintaining diverse CSO habitat throughout the landscape (Roberts et al. 2011, p. 617; Stephens et al. 2019, p. 394).

Summary of Fuels Reductions and Forest Management

Fuels reductions and forest management practices within the CSO range include clearcutting, mechanical thinning, salvage logging, and prescribed fire. Depending on the method used and how it is implemented, fuels reductions and forest management practices can have both positive and negative influences on the species. There are no regulatory mechanisms or conservation

measures that completely ameliorate the negative impacts of fuels reductions and forest management practices to CSO; land management direction including the Sierra Nevada Forest Plan Amendment include protective standards and guidelines that must be adhered to while conducting management activities in CSO habitat (see 4.9 Regulatory Mechanisms and Management Actions). Available information suggests that fuels reduction in some form is necessary to ensure CSO habitat persistence because long-term gains in habitat protection outweigh the short-term negative effects, especially when conservation measures are implemented appropriately (Jones et al. 2021b, p. 2, a, p. entire; North et al. 2022, p. entire; Safford et al. 2022, p. entire). Differences in forest management may help explain why CSO populations occurring in some mixed ownership landscapes have higher occupancy, density, and probability of reproduction compared to public land (Roberts et al. 2017, p. 113; Hobart et al. 2019, p. 198; SPI 2022, pp. 9, 17). The need to increase the pace and scale of fuels reduction efforts is recognized across agencies and recently, the Department of the Interior announced funding through the Bipartisan Infrastructure Law to increase fuels treatments across the United States (DOI 2022, entire). The Forest Service also identified preliminary projects to address fuel reduction projects through the "Wildfire Crisis Landscape Investments," and two projects are expected in the near-term within the CSO range that include mechanical thinning and prescribed fire (Tahoe National Forest and the Stanislaus National Forest; (Forest Service 2022a, p. entire). Fuels reductions and forest management practices will likely continue to have varied effects on CSO throughout the species' range.

4.6 Competition and Hybridization with Barred Owls

The barred owl (*Strix varia*) is a closely related species to the spotted owl, native to eastern North America (Mazur and James 2000, "Introduction" Section). Since the 1960s, the barred owl has been extending its range westward, first coming in contact with northern spotted owls and more recently moving into the CSO range (Peterson and Robins 2003, p. 1162; Livezey 2009, p. 49; Keane et al. 2018, p. 5). Long and Wolfe (2019, p. 1282) includes a figure with panels demonstrating the range of barred owls from their historical range into western North America, with progression into the ranges of northern, California, and Mexican spotted owls. The barred owl range completely overlaps the northern spotted owl range (Wiens et al. 2020, p. 1), and much of the CSO range (Keane et al. 2018, p. 38). Relevant to CSO, barred owls were first detected in northwestern California in 1982 (Evens and LeValley 1982, p. 890), the Sierra Nevada in 1991 (Dark et al. 1998, p. 53), and along the coast as far south as Marin County in California by 2002 (Jennings et al. 2011, p. 105). Barred owls and spotted owls have similar habitat requirements, with old forests representing high-quality habitat for both, although barred owls use a broad mix of forest types (Wiens et al. 2014, pp. 14, 32). Because barred owls have more habitat flexibility than spotted owls, there is potential for barred owls to expand into spotted owl habitat through corridors of lower-quality habitat. For example, there are recent barred owl sightings from Davis, California (ebird.org, accessed 14 April 2022), suggesting barred owls could expand into CSO habitat from the west in addition to the more likely pathway through forests in the Sierra Nevada. Although the CSO range has a gap between the Sierra Nevada and southern California, barred owls may be able to colonize the southern California CSO range because of their ability to use other forest types. Detections of barred owls in coastal forests in the Santa Cruz Mountains in San Mateo County, California (ebird.org, accessed 14 April 2022), an area notably absent within the CSO range (see 2.2

Geographic Distribution), suggests a pathway towards connectivity to the coastal CSO portion of the range.

Barred owls are aggressively outcompeting and displacing spotted owls on the landscape (Wiens et al. 2014, p. 1; Gutiérrez et al. 2017, p. xvi; Long and Wolfe 2019, entire). Barred owls are larger than spotted owls (Gutiérrez et al. 2007, pp. 185–186) and behaviorally dominant (Van Lanen et al. 2011, pp. 2197–2198). Although diet overlaps between the two species, with both predominantly feeding on nocturnal mammals, barred owls are generalists that consume many more prey species in comparison to spotted owls (Wiens et al. 2014, pp. 24–25; Kryshak et al. 2022, pp. 12–13). Competition between the two species results in negative effects to the survival, productivity, and recruitment of northern spotted owls (Dugger et al. 2016, pp. 69–91) and barred owls have been described as demographically superior to northern spotted owls because they have higher survival estimates and produced on average 4.4 times more young than northern spotted owls over a 3-year study period (Wiens et al. 2014, p. 28). The presence of barred owls has caused lower detection rates and occupancy probabilities in northern spotted owls (Olson et al. 2005, p. 918; Crozier et al. 2006, p. 760; Kroll et al. 2010, p. 1264; Yackulic et al. 2012, p. 1953, 2014, p. 265). Although there is some evidence that lower detection rates may be in part due to northern spotted owls responding less frequently in the presence of barred owls (Crozier et al. 2006, p. 760), the negative effects of barred owls on spotted owls are clear. Although there is no evidence of barred owls wounding or killing northern spotted owls (Wiens et al. 2014, p. 33), competition ultimately has population-level effects because of impacts to occupancy and reproduction. Additionally, barred owls can hybridize with spotted owls (Gutiérrez et al. 2017, p. 211). There are likely broader impacts on the ecosystem of the barred owl range expansion such as an imbalance in predator/prey relationships, causing even greater impacts to spotted owl interspecific competition (Holm et al. 2016, p. 615). Because of the wide and diverse diet of barred owls in comparison to spotted owls, (Kryshak et al. 2022, pp. 15–16) argue that barred owls will not be ecological replacements to the spotted owls that they displace, and this could have widespread ecological impacts.

Barred owl detections within the spotted owl range have continued to increase. From 1989 to 2013, 51 barred owls and 27 barred owl/spotted owl hybrids had been detected in the Sierra Nevada (Gutiérrez et al. 2017, p. xxv). By 2017, the number of barred and barred owl/spotted owl hybrid detections in the Sierra Nevada increased to approximately 145 (Keane et al. 2018, p. 7), with another 2.6-fold increase between 2017 and 2018 (Wood et al. 2020, p. 4). Even these seemingly low numbers of barred owls in the CSO range are of concern, given that in the northern spotted owl range, replacement of northern spotted owls began at a slow rate in the early years of the expansion, followed by a rapid rate of replacement once the barred owl population reached a critical mass (Forsman in litt. 2018, p. 1). Recent observed CSO population declines likely do not yet reflect barred owl impacts (Gutiérrez et al. 2017, p. 99). In the summer of 2017, bioacoustic surveys in Lassen National Forest, the northern end of the CSO range, found that barred owls were approximately five times less abundant than spotted owls (Wood et al. 2019, p. 498). From 2017–2018, a rapid increase in barred owls was observed in Lassen National Forest with site occupancy changing from 0.082 (CI 0.045-0.12) to 0.21 (CI 0.14-0.28) (Wood et al. 2020, p. 4). As shown in Figure 10, barred owl detections in the CSO range have increased over the almost thirty-year period of 1989–2017. Figure 11 represents barred owl individual locations within the CSO range over two

time periods: pre-1990 through 2009 and 2010 through 2022. As shown, over the last 10 years in particular, barred owl detections throughout the CSO range have increased.

Experimental barred owl removal studies were first initiated and are currently ongoing in the northern spotted owl range (Diller et al. 2012, p. entire; Wiens et al. 2020, p. entire). Wiens et al. (2020, p. entire) summarizes efforts to remove barred owls using a before-after-control-impact design in three study areas in Washington and Oregon, which resulted in removals of over 2,000 barred owls from 2015 through 2019. Results indicate that removals successfully decreased site use by barred owls and increased northern spotted owl use within treatment areas. Further, successful barred owl removals can result in competitive release for spotted owls (Wiens et al. 2021, pp. 4–5). In another (smaller) example of barred owl removals within the northern spotted owl range, after nine barred owls were removed from historical northern spotted owl sites, all sites were re-occupied by northern spotted owls within a year of removal: four by the original residents and five by new residents (Diller et al. 2012, p. 405). However, barred owls again replaced the northern spotted owls at 3 sites within 1–4 years of the northern spotted owls reoccupying those territories (Diller et al. 2012, p. 405). Overall, evidence to date indicates some measure of success for northern spotted owls related to barred owl removal efforts in at least some cases. However, species experts caution that forest conditions, densities of barred owls, and numbers of spotted owls would all factor into whether or not similar results could be obtained in other areas (Wiens et al. 2020, p. 1).

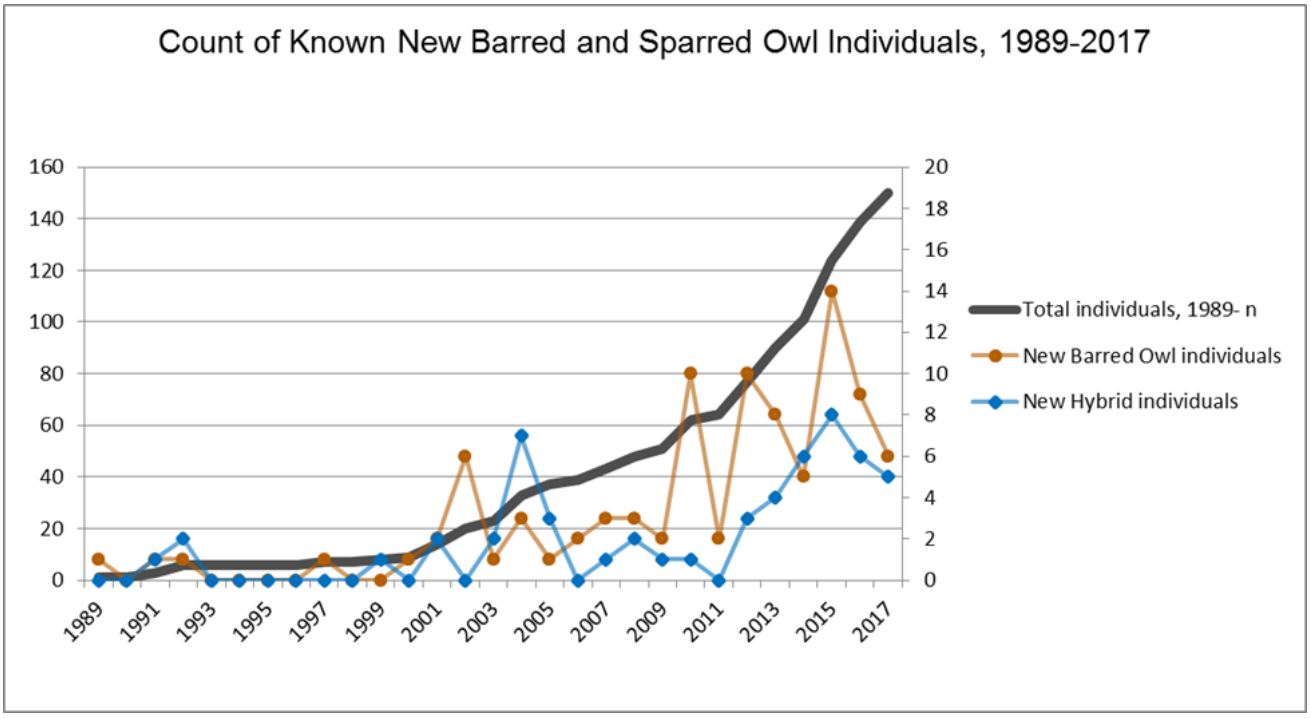


Figure 10: Figure from Keane et al. 2018 shows the barred owl expansion in the CSO range through time. The left y-axis represents the total number of individuals, and the right y-axis represents the number of new barred and hybrid individuals (i.e., sparred owls) each year.

Experimental barred owl removal studies have also recently been initiated in the CSO range, specifically in the Sierra Nevada (Hofstadter et al. 2022, p. entire). In 2017, a CSO conservation

assessment concluded that control measures for barred owls in the CSO range were likely to be more successful and cost efficient while densities of barred owls are still relatively low in the CSO range, and that if control measures were not taken, barred owls would most likely replace CSO on the landscape in the future (though the timescale of this replacement was uncertain) (Gutiérrez et al. 2017, pp. xxxi, xxv); see also (Wood et al. 2020, pp. 5–7). Within the CSO range, barred owl removal experiments were initiated in 2018 and have continued through 2022 (Hofstadter et al. 2022, p. entire). Between 2018 and 2020, researchers removed 76 owls (63 barred owls and 13 hybrids) from the Sierra Nevada, decreasing barred owl occupancy by a factor of 6.3 down to 0.03 (confidence interval: 0.01–0.04). Experimental removals were guided by passive acoustic monitoring, which was also used to measure the efficacy of removals. Partnerships were crucial to the regional-scale removal, with public-private partnerships allowing access to 92% of the CSO range in the Sierra Nevada, including almost all known barred owls in the area and minimizing refugia for barred owls. California spotted owls rapidly colonized territories where barred owls were removed: 15 out of 27 territories were recolonized by CSO within one year of barred owl removals, with successful breeding documented in five of these territories (Hofstadter et al. 2022, pp. 4–5). Early and effective

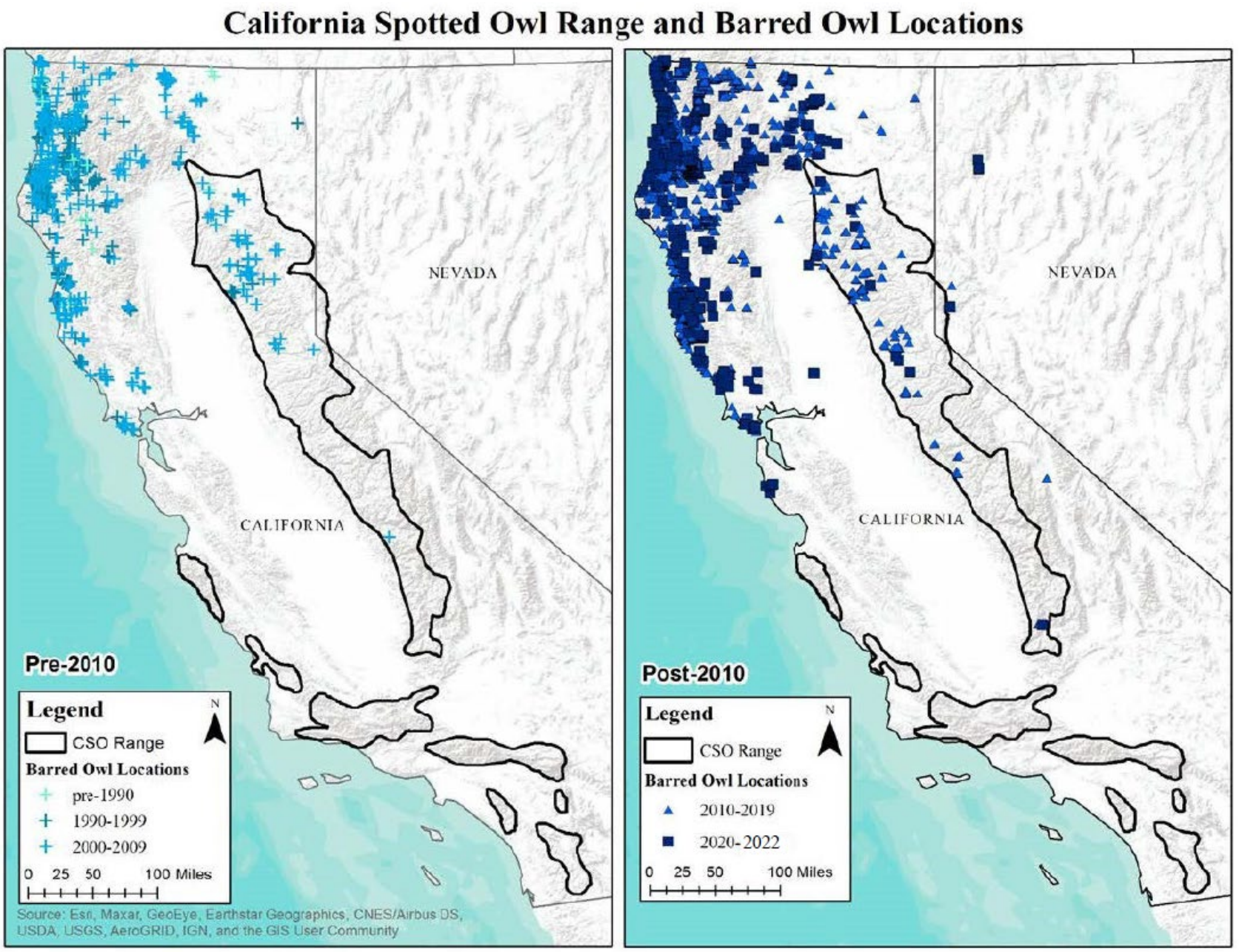


Figure 11: Barred owl detections within the California spotted owl range (eBird 2022; CNDDB 2022). Each point does not necessarily represent a unique individual, but rather a separate detection.

experimental removals of barred owls within the CSO range in the Sierra Nevada has dampened the urgency of this threat, but the potential for continued and persistent expansion into the range remains. Funding is currently available to continue barred owl removal experiments in the California extent of the Sierra Nevada through 2024 (Peery in litt. 2022). However, continued barred owl monitoring and experimental removal would likely need to continue into the future (Hofstadter et al. 2022, p. 6). Management options are currently being evaluated for potential future implementation.

Regulatory mechanisms and management actions that are providing or could potentially provide some protection from the effects of barred owl expansion include management teams, management plans, and Habitat Conservation Plans (HCPs) that coordinate, fund, and implement the experimental removals described above. For more information about the management teams, management plans, and HCPs that ensure these efforts occur, see 4.9 Regulatory Mechanisms and Management Actions. However, barred owls are a significant threat to the persistence of California spotted owls, and the magnitude of this threat is expected to increase into the foreseeable future, particularly if management efforts are not continued.

4.7 Rodenticides

Exposure of nontarget wildlife to anticoagulant rodenticides threatens many species, including CSO, likely because of ingestion of prey animals that have been exposed (Gabriel et al. 2018, p. 5; Franklin et al. 2018, p. 2). Secondary exposure to anticoagulant rodenticides in predators such as raptors can be lethal, with higher exposure levels causing severe blood loss and internal hemorrhaging that can result in organ failure and death (Gomez et al. 2022, p. 147). Although this threat has potential impacts to individuals, because CSO is a long-lived species with low reproductive rates, the loss of just a few individuals may reduce survival and the population growth rate. This threat would be particularly detrimental if a parent were exposed during breeding season because hatchlings and juveniles rely on parental care to survive, so the loss of just one parent would likely result in the loss of offspring as well. Rates of mortality in free-living wild birds due to anticoagulant rodenticides are often unknown due to the difficulty of linking exposure to death and the lack of understanding of toxicity thresholds in different species (Gomez et al. 2022, pp. 147–148). Documentation of anticoagulant rodenticides in ovaries of female barred owl suggests the possibility for in-utero transfer to chicks (Hofstadter et al. 2021, pp. 7–8). Sub-lethal effects of anticoagulant rodenticides in other owl species include reduced clutch size, brood size, fledging success, slower clotting time, residual transfer to eggs, anemia, and impaired mobility; however, these impacts have not yet been documented in spotted owls (Rattner et al. 2012, p. 832; Salim et al. 2014, p. 113; Gabriel et al. 2018, p. 7; Gomez et al. 2022, p. 148).

Although there is little information specific to CSO regarding the exposure rates and resulting impacts of rodenticides, available literature on other species suggests the potential for widespread exposure. Exposure of nontarget species to anticoagulant rodenticides is commonly associated with agricultural or urban settings, but exposure in forest settings in northern California has recently been documented as detrimental to northern spotted owls and barred owls in northern California (Gabriel et al. 2018, p. 5; Franklin et al. 2018, p. 2). Seven out of ten northern spotted owl carcasses tested positive for anticoagulant rodenticides, and 40% of 84 barred owls tested in the northern spotted owl range had been exposed (Gabriel et al. 2018, pp. 4–5). In another study using barred owls as a proxy for spotted owls, Wiens et al. (2019, p. 4) demonstrated exposure to

anticoagulant rodenticides in almost half of barred owls sampled (n=40) and one northern spotted owl sampled opportunistically. Exposure did not vary based on proximity to developed and agricultural areas, or among different study areas, age-classes, and sexes in the study. High rates of exposure were also demonstrated in barred owls and barred owl/spotted owl hybrids in California, with females having higher rates of exposure than males (Hofstadter et al. 2021, pp. 6–7). Despite some differences in diet between barred owls and spotted owls (generalist vs. specialist), comparison of space use by tagged barred owl, northern spotted owl, and CSO in areas with high barred owl anticoagulant rodenticide exposure supports the use of barred owls as a proxy for spotted owls (Hofstadter et al. 2021, pp. 7–8). Large amounts of rodenticides and other pesticides have been found on Forest Service land in the southern Sierra Nevada (Thompson et al. 2013, pp. 95–99). Studies examining rodenticide exposure rates of fisher (*Martes pennanti*), a carnivorous predator with similar habitat requirements as CSO, found 83% to 85% of carcasses studied in the Sierra National Forest had been exposed to rodenticides (Gabriel et al. 2012, pp. 1–14; Thompson et al. 2013, p. 91). These data also suggest potential exposure to CSO.

Anticoagulant rodenticide use has increased throughout California with increases in illegal marijuana cultivation since anticoagulant rodenticides are used to control rodent damage to the plants (Franklin et al. 2018, p. 1). Figure 12 presents marijuana grow sites that have been found in California within the CSO range and MAXENT model results that were developed to predict likelihood of locations of marijuana grow sites (Gabriel et al. 2017, p. 32). Modeling to compare marijuana cultivation site likelihood with northern spotted owl suitable habitat found almost 50% overlap between the two (Wengert et al. 2021, p. 10). Although the exact number of illegal marijuana growing operations within the CSO range is unknown, considering the number of illegal marijuana growing operations found throughout the state, there are likely thousands within the CSO range (Gabriel et al. 2012, pp. 12–13, 2018, p. 6; Thompson et al. 2013, pp. 95–99).

In 2014, the California Department of Pesticide Regulation restricted the purchase, possession and use of anticoagulant rodenticides to only be purchased and used by a certified pesticide applicator with a permit issued by the county agricultural commissioner in order to protect wildlife; however, anticoagulant rodenticides associated with illegal marijuana grows are more likely the source of contaminants. If illegal marijuana grows are found, law enforcement will shut the operations down, but there is currently no standardized clean-up protocol and a limited amount of funding to ensure removal of all rodenticides. Recently there has been an increased effort to locate and shutdown illegal marijuana grows on public lands in California called Operation Forest Watch (DOJ 2018, p. entire). For more information about efforts to address illegal use of rodenticides, see 4.9 Regulatory Mechanisms and Management Actions. Overall, anticoagulant rodenticides are likely affecting CSO across their range, and this threat is expected to continue into the foreseeable future.

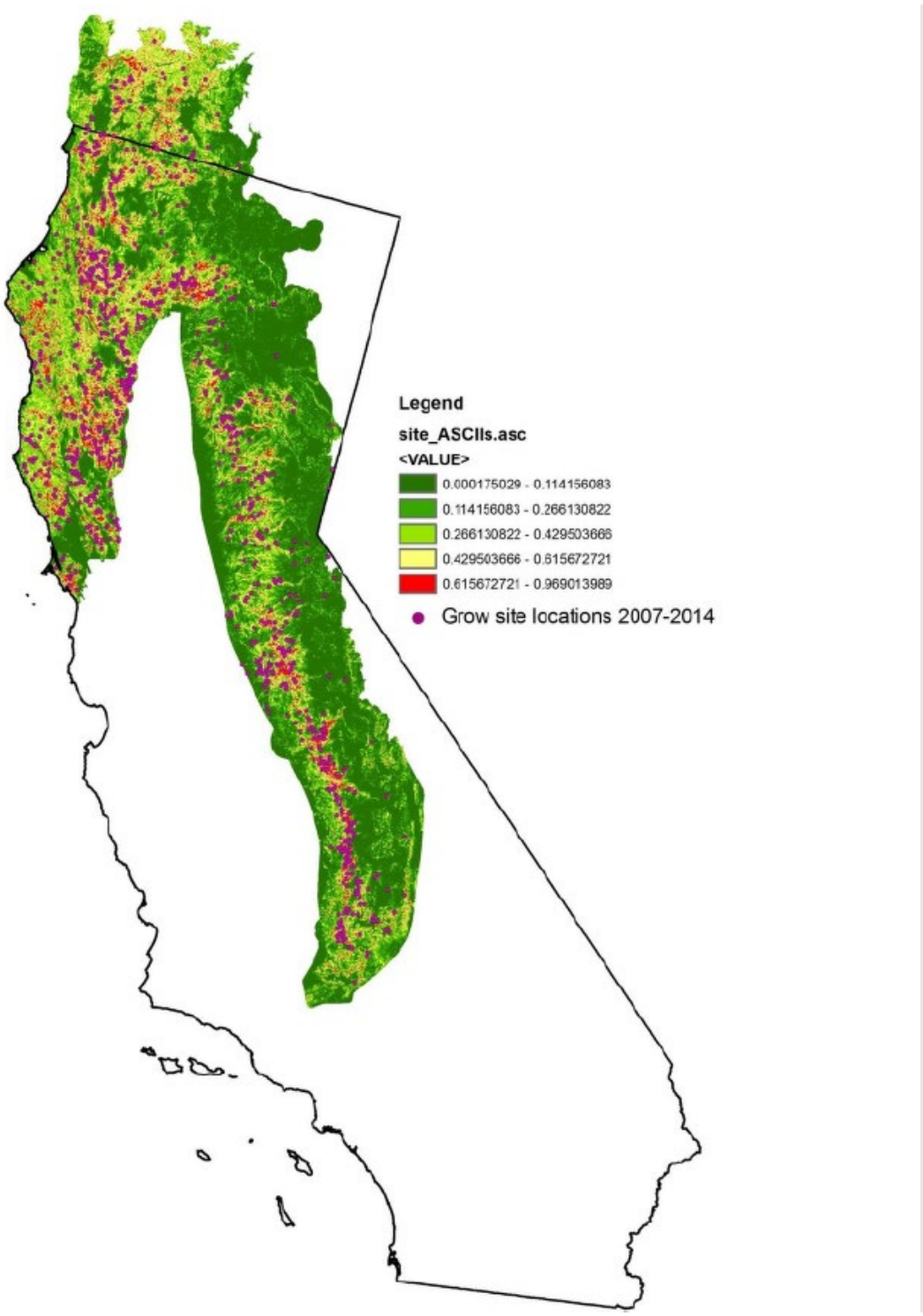


Figure 12: Figure from the Service's Endangered Species Act (Section 6) Grant-in-Aid Program Administered by CDFW, Science with Solutions: Documentation, Reclamation and Monitoring of the Ecological Impacts of Marijuana Cultivation on Endangered Species (Gabriel et al. 2017, p. 32). Map of likelihood of marijuana grow site presence based on MAXENT predictions using known grow site localities and several biotic and abiotic features as predictors. Red areas represent highest relative likelihood of grow sites presence, while yellow is moderate likelihood, and green is low-likelihood.

4.8 Development

Anthropogenic land use (including both cultivation and development) in California is expected to increase 28% by 2100 with a projected 3% decrease in overall forest land cover (Sleeter et al. 2017, pp. 1068, 1075). Urbanization is projected to be a primary driver of land use and land cover change in California over this time frame (Sleeter et al. 2017, p. 1076). Urban development is a threat throughout the range of CSO; however, the threat is more substantial in the coastal and southern California areas (Sleeter et al. 2017, pp. 1081, Figure 6, Figure 7). A majority of CSO habitat occurs on public lands (~71% of total range); therefore, this threat is primarily relegated to a small amount of private lands. Future projections for development are unknown within the CSO range because much of the current range occurs on public lands.

In southern California, there are high development demands with specific threats of wind farms and large reservoirs impacting connectivity within the CSO range (Gutiérrez et al. 2017, pp. 253–254). Loss of riparian areas due to water diversion in southern California has created barriers to dispersal among small populations (Gutiérrez et al. 2017, pp. 253–254). The southern California area of the CSO range is fragmented, with low dispersal between populations, so more development could further exacerbate fragmentation (LaHaye et al. 2001, p. 692; Barrowclough et al. 2005, p. 1116; Gutiérrez et al. 2017, pp. 253–254)

In the Sierra Nevada, low to mid elevation development is considered a threat to CSO and its habitat (Verner et al. 1992, pp. 264–265). Low and mid elevation zones in the Sierra Nevada continue to experience human population growth, which may increase the demand for development. Fifty percent of known CSO sites on the west slope of the Sierra Nevada are considered wildland-urban interface and may be vulnerable to further development (Gutiérrez et al. 2017, p. 207). Spotted owls living near the wildland-urban interface may be at a higher risk for exposure to anticoagulant rodenticides, as is the case for barred owls and hybrids (Hofstadter et al. 2021, p. 8); see 4.7 Rodenticides). The northern Sierra Nevada is expected to have a higher level of forest harvest compared to other parts of the CSO range (Sleeter et al. 2017, pp. 1081, Figure 7). Overall, development is likely affecting owls across their range, and we expect this threat will continue into the foreseeable future.

4.9 Regulatory Mechanisms and Management Actions

In this section we include information about regulatory mechanisms in place that provide protection for CSO or reduce or eliminate impacts to habitat. We describe each mechanism or action and how it relates to the species or its habitat, noting that some mechanisms do not actually carry formal legal status or provide formal regulatory protections. Mechanisms and actions include state and federal codes, designations, or acts, federal incidental take permits, and forest management on Forest Service lands. Other conservation or management actions are described under the relevant viability influence (e.g., barred owl removal research is described in 4.6 Competition and Hybridization with Barred Owls). Below we summarize the current conservation efforts and regulatory mechanisms that provide benefits specifically for CSO and its habitat.

U.S. Forest Service Management

The U.S. Forest Service has been a part of ongoing conservation efforts for CSO including the 2004 Sierra Nevada Forest Plan Amendment, which includes Forest Service land in the Lassen, Plumas, Tahoe, Humboldt-Toiyabe, Eldorado, Stanislaus, Sierra, Inyo, and Sequoia CSO analysis units, and the 2005 Southern California National Forest Land Management Plans, which includes the Los Padres, Los Padres-Angeles, San Bernardino, and Cleveland CSO analysis units. In 2019, the Inyo National Forest completed its own Land Management Plan and revised Forest Plans for the Sierra and Sequoia National Forests are expected to be final in 2023 (Miller in litt. 2022.). Once these Plans are finalized, the Inyo, Sierra, Sequoia National Forests will no longer follow the 2004 Sierra Nevada Forest Plan Amendment. All of these are regulatory documents that provide conservation measures for CSO on Forest Service lands (Forest Service 2004, 2005, p. entire, 2019a, pp. 43–47, 2022b, pp. 59–68, c, pp. 59–68). The main goals of these conservation measures include protection and management of CSO activity centers and home range core areas, increasing the frequency of large trees on the landscape, and increasing structural habitat diversity. The goals relate to increasing the condition of the species' ecological needs to increase resiliency and provide conservation efforts related to the threats of large-scale high-severity fire, clearcutting, mechanical thinning, and salvage logging.

The 2004 and 2005 Forest Service land management plans and the 2019 Inyo National Forest and 2022 version of the Sierra and Sequoia National Forest Plans maintain the designation of PACs for CSO, which encompass the best available 121 ha (300 ac) of habitat in as compact of a unit as possible around a nest tree (Forest Service 2004, p. 37; Forest Service 2005, p. 109; Forest Service 2019a, p. 43; Forest Service 2022b, p. 61; Forest Service 2022c, pp. 61–62). There are special considerations for any land management activities or projects that may take place within a PAC. Depending on the plan, management standards and guidelines can include conducting surveys during the planning process of vegetation treatments where appropriate (i.e., in areas of suitable habitat for CSO), limiting activities to reducing surface and ladder fuels through prescribed fire, limiting mechanical treatments to only allow fuel reduction treatments in some wildland urban defense zones where prescribed fire is not feasible, identifying maximum size of canopy gaps created within CSO territories, requiring a limited operating period for when vegetation treatments can occur, and limiting the impacts a vegetation treatment can have on a PAC per year (Forest Service 2004, pp. 54, 60–61, 2022b, p. 64, c, p. 64). The limited operating period is March 1 through August 15 or August 31, unless surveys confirm CSO are not nesting or the treatment is limited such that it would not disturb breeding (Forest Service 2004, p. 60, 2019a, p. 46). Under the 2004 Sierra Nevada Forest Plan Amendment, the limited operating period may also be waived when early season prescribed fire is necessary, but in only up to 5% of PACs per year on a forest (Forest Service 2004, p. 61). Under the 2019 Inyo National Forest and 2022 version of the Sierra and Sequoia National Forest Plans this waiver applies to up to 10% of the PACs per year on a forest (Forest Service 2019, p. 47; Forest Service 2022b, p. 67; Forest Service 2022c, p. 67). The Sierra Nevada Forest Plan Amendment specifies vegetation treatments cannot be conducted in more than 5% per year and 10% per decade of the acres in PACs for each Sierra Nevada area national forest (Forest Service 2004, p. 61); however, this is not described in the 2019 Inyo National Forest Plan or the 2022 version of the Sierra and Sequoia National Forest Plans. In addition to protections, the 2004 Sierra Nevada Forest Plan Amendment and the 2022 version of the Sierra and Sequoia National Forest Plans outline desired conditions for PACs and other large habitat blocks within the home range that include at least two tree canopy layers, dominant and co-dominant trees with average diameters of at

least 61 cm (24 in) dbh, at least 60% to 70% canopy cover, some very large snags (greater than 114 cm (45 in) dbh), and snag and course woody debris levels that are higher than average (Forest Service 2004, pp. 37, 39–40). As discussed below, in April 2019, the Forest Service finalized a new CSO conservation strategy for the Sierra Nevada (Forest Service 2019b). The intention of the strategy is to be used for adaptive management and to be incorporated into future Forest Plan updates, although it is not legally enforceable and does not commit and agency action or inaction.

There is disagreement about whether or not measures in these plans, such as mechanical thinning, are beneficial or detrimental to CSO, and whether or not protections afforded by PACs are sufficient to ameliorate impacts to CSO (John Muir Project of Earth Island Institute and The Wild Nature Institute 2014, pp. 70–71, 98, 108; Sierra Forest Legacy and Defenders of Wildlife 2015, pp. 39–40). However, a meta-analysis of CSO occupancy and forest management practices indicated that mechanical thinning treatments that maintain canopy cover at 40% or greater would not substantially reduce CSO occupancy, though canopy cover at 50% or above is more strongly correlated with CSO occupancy (Tempel et al. 2016, pp. 761–762). Forest management practices from the 2004 Sierra Nevada Framework generally maintain at least 50% canopy cover as well as large trees within PACs, and in the 2005 Southern California plan, 40–50% canopy cover must be maintained. The 2019 Conservation Strategy also maintains a minimum of 50% canopy cover within PACs (Forest Service 2019b). Overall, PACs are designated to preserve key habitat used by CSO, and some researchers have concluded that PACs are a key conservation tool that should continue to be implemented (Berigan et al. 2012, pp. 300, 303). In contrast, other research has shown that PACs can be more susceptible to the effects of high-severity fire due to the relatively larger amounts of surface fuel (North et al. 2012, p. 395). A recent study of GPS tagged CSO in the northern Sierra Nevada demonstrated little overlap between PACs and roost or foraging locations, though PACs were not designed to protect foraging habitat (Blakey et al. 2019, p. 920).

In addition to these regulatory documents, the Forest Service has been engaged in four of the five demography studies since 1986 on Lassen, Eldorado, Sierra, and San Bernardino National Forests to increase understanding of CSO ecology and conservation needs. The Forest Service fully funded the four demography studies from 1990–1998, and although they have started to transition to a new monitoring method that covers the species', the Forest Service continued to fund three demography studies on Lassen, Eldorado, and Sierra National Forests, with the Service contributing funding to continue the Lassen and Sierra National Forests through 2024. Due to the transition to the new monitoring method, the Eldorado study area is currently unfunded for 2022 and beyond (Peery 2022, pers. comm.). The San Bernardino demography study was also discontinued in 1998 due to funding constraints. Data collected from these studies have been used to calculate population and occupancy trends, habitat selection and suitability, life history strategies, genetics and phylogeny, and post-fire and post-disturbance distribution. In lieu of continuing these demography studies, the Forest Service is working with the University of Wisconsin Madison to deploy Autonomous Recording Units throughout the Sierra Nevada to determine species presence (Keane and Peery 2022, pers. comm.). Utilizing this newly emerging technology will hopefully allow researchers to identify individual owls on the landscape in the future (Zhou et al. 2020).

In April 2019, the Forest Service completed an updated CSO conservation strategy for the Sierra Nevada national forests (Forest Service 2019b, p. entire). The updated strategy includes new

scientific understanding since the 2004 Sierra Nevada Forest Plan Amendment and will be incorporated into the National Forest Land Management Plans as they are updated in the coming years according to the Forest Service 2012 Planning Rule as amended (36 CFR Part 219). Until the revised National Forest Land Management Plans can be completed, a letter of direction was sent to the Sierra Nevada national forests on April 19, 2019 to provide guidance on implementing the new conservation strategy in the interim (Forest Service 2019c, p. entire). The new conservation strategy gives direction for increased pace and scale of ecological restoration to provide more resilient habitat for CSO, while simultaneously continuing to protect the most important habitat attributes and areas for CSO. The three main goals for the 2019 conservation strategy include: (1) maintain a well-distributed and stable CSO population across the Sierra Nevada by minimizing impacts from non-habitat threats (i.e., barred owls and contaminants); (2) promote and maintain well-distributed CSO habitat by developing key habitat elements and connectivity; and (3) promote CSO persistence by enhancing habitat resilience to multiple disturbances, considering climate change. This increased habitat resilience will lead to improved conditions on the landscape, and greater population resiliency. The new strategy provides adaptive management and metrics for success in order to ensure the conservation measures outlined in the plan are beneficial to CSO. In addition to the conservation strategy, the Forest Service is planning to implement a new monitoring plan using acoustic recording units to cover the Sierra Nevada portion of the CSO range. The goal is to use the information from the new monitoring plan to allow the Forest Service to conduct a future CSO occupancy modeling effort to provide information over a larger portion of the CSO range, and allow greater potential for inference on broad scale effects of restoration and disturbance (Forest Service 2019d, pp. 14–15). There are elements of the strategy that may entail some short-term, localized reduction in occupancy. These elements allow for more forest management flexibility in application of fuels reduction and other landscape treatment projects as compared to the 2004 Sierra Nevada Forest Plan Amendment both within PACs and on the landscape, as well as more flexibility in the retirement of PACs when they are no longer occupied. Additional flexibility in these landscape treatments provides access to additional tools to maintain and restore CSO habitat (Forest Service 2019b, p. entire). We anticipate that the short-term impacts that may occur for the purpose of fuel reduction and forest health will be outweighed by the long-term benefit as more sustainable and dynamic habitat is developed through active management (Forest Service 2019b, p. 2).

On August 30, 2017, a Memorandum of Understanding (MOU) was signed by Sierra Pacific Industries (SPI), California Department of Forestry and Fire Protection (CAL FIRE), National Fish and Wildlife Foundation (NFWF), and U.S. Department of Agriculture, U.S. Forest Service Pacific Southwest Region (hereafter referred to as the Fire MOU), which will impact all lands from Lassen National Forest south through Stanislaus National Forest. The purpose of the MOU is to document the agreement between the parties to coordinate on certain actions to reduce the risk of large-scale high-severity wildfire through forest fuels reduction to benefit CSO conservation. The MOU involves establishing a strategic conservation framework to help restore and protect areas where CSO are threatened by habitat degradation due to uncharacteristically extensive and severe adverse fire effects. The MOU is designed for signatories to engage in collaborative landscape-level fuels and fire risk reduction treatments to: 1) minimize potential fire-related impacts to CSO activity centers on federal, state and private lands; and 2) better coordinate implementation of fuels reduction work on federal, state, and private lands to maximize the effectiveness of this work. Sites for fuels treatment are selected to minimize risk to known occupied CSO activity centers. Measures

associated with the Fire MOU include fire management activities such as increased mechanical thinning that may benefit CSO by decreasing risk of large-scale high-severity fire. If mechanical thinning is planned in consideration of CSO habitat needs, there may be some negative impacts, but these would be outweighed by reducing the risk of large-scale high-severity fire in CSO activity centers (Jones et al. 2016a, p. 305, 2021a, p. 6; Service 2017, pp. 24–25; Chiono et al. 2017, p. 1).

The Forest Service, SPI (a private corporation), and CAL FIRE manage forest lands in California that are frequently adjacent to each other, and have ongoing programs to protect and enhance habitat for fish and wildlife and also manage forest fuels to reduce fire risk and its potential impacts on wildlife species. Under state law, SPI has the authority to participate in fire suppression on its own lands while CAL FIRE, contract counties, Forest Service, and other government agencies have primary fire suppression responsibility for all federal, state, and private wildlands in California. The parties also have responsibilities and interests in the inventory of their respective lands for federally- and state-recognized threatened, endangered, proposed, candidate, and sensitive species and in the development of appropriate protection measures for these species. Due to these natural resource challenges, the Fire MOU parties believe it is important to establish a coordinated, multi-stakeholder agreement to help protect and enhance forest resources.

Though the Fire MOU was initially set to expire on December 2019, an amendment was signed in April 2019 to extend the terms of the MOU through December 2024. In March 2020, a new MOU that supersedes the 2017 MOU and 2019 amendment was signed by the same parties. An amendment to the 2020 MOU was signed in September 2020 to add a number of new commercial forest landowners. The terms of the 2020 MOU are effective through December 2024. The Service is actively engaged with the signatory parties to discuss fuels reduction efforts and associated monitoring.

Barred owls (*Strix varia*) have expanded into western North America over the past several decades, first through the Pacific Northwest and more recently into the Sierra Nevada (see 4.6 Competition and Hybridization with Barred Owls). The Service and the Forest Service are funding researchers at the University of Wisconsin-Madison to carry out an ongoing barred owl removal study. The project grant was signed in August of 2018 and funding has been secured from the Service and potentially University of Wisconsin-Madison through 2025 (Keane and Peery 2022, pers. comm.). The project addresses several key questions related to the range expansion of barred owls in the Sierra Nevada and will inform the development of a scientifically-based barred owl management plan. Specifically, this project: (1) assesses the current distribution and density of barred owls; (2) conducts experimental barred owl removals; (3) tests for reductions in barred owl site occupancy rates; 4) quantifies spatio-temporal patterns of barred owl recolonization; and 5) characterizes barred owl dispersal into and within the Sierra Nevada. This project takes place primarily in the northern and central Sierra Nevada, including Lassen National Forest, Lassen National Park, Plumas National Forest, Tahoe National Forest, and Eldorado National Forest, Yosemite National Park, and Sequoia-Kings Canyon National Park.

Additionally, on July 22, 2022, the Service published a Notice of Intent to prepare an Environmental Impact Statement (EIS), initiating a 30-day public scoping period seeking input on barred owl management in the northern spotted owl and CSO range (87 FR 43886). Preventative barred owl management for CSO will likely be considered in the EIS. Northern spotted owl are the

main focus right now, but barred owl have expanded into northern California into the CSO range and are expected to continue to expand without continued management.

Migratory Bird Treaty Act

The CSO is currently protected in part under the Migratory Bird Treaty Act (MBTA) which is intended to ensure the sustainability of populations of all protected migratory bird species (16 U.S.C. 703–712). These protections make it "illegal for anyone to take, possess, import, export, transport, sell, purchase, barter, or offer for sale, purchase, or barter, any migratory bird, or the parts, nests, or eggs of such a bird except under the terms of a valid permit issued pursuant to Federal regulations." The MBTA provides regulatory protection to individuals that could be targeted via trapping, shooting, or direct poisoning.

The level of protection a migratory bird species has received under the MBTA has changed based on varying memorandums. The U.S. Department of the Interior's Office of the Solicitor (solicitor) issued a memorandum opinion (M-Opinion 37050) to the Director of the Service on December 22, 2017, providing a legal analysis for the interpretation of the MBTA to only include purposeful take and not incidental take. Based on this analysis, M-Opinion 37050 concluded that the MBTA's prohibition on take "applies only to direct and affirmative purposeful actions that reduce migratory birds, their eggs, or their nests, by killing or capturing, to human control" . However, on March 8, 2021, the Principal Deputy Solicitor of the Interior issued a memorandum withdrawing Solicitor's Opinion M-37050. Therefore, the incidental take of eggs and/or nestlings during timber harvest activities and during the destruction of active nest trees are a violation of the MBTA.

Fish and Wildlife Conservation Act

Under the Fish and Wildlife Conservation Act, the Service considers CSO a Bird of Conservation Concern and a Bird of Management Concern; however, neither of these designations offers regulatory protection. Inclusion as a Bird of Conservation Concern is "intended to stimulate coordinated and collaborative conservation actions among Federal, State, Tribal, and private partners…" for the species and "…to prevent or remove the need for additional…bird listings…" under the Endangered Species Act. Birds of Management Concern are species which are protected under the MBTA and "warrant management or conservation attention."

Habitat Conservation Plans

The Service may issue incidental take permits to non-federal applicants pursuant to section 10(a)(1)(B) of the Endangered Species Act. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 402.02). Habitat conservation plans (HCPs) are planning documents required as part of an application for an incidental take permit; HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. They describe the anticipated effects of the proposed taking; how those impacts will be minimized or mitigated to the maximum extent practicable; and how the HCP is to be funded. There are currently two HCPs that include CSO.

Sierra Pacific Industries

Sierra Pacific Industries (SPI) is the largest private forest land owner in California, with approximately 1.84 million acres of timberland in northern California (SPI 2021, p. 1). Sierra Pacific Industries' Habitat Conservation Plan for both northern spotted owl and CSO cover all areas on SPI-managed property where covered activities will occur within the range of the two spotted owl subspecies, which is over 1.5 million acres ([SPI] Sierra Pacific Industries 2021, p. 2). The plan area for CSO includes approximately 1,188,265 acres of modeled habitat in the Modoc Plateau, Cascade Mountains, and Sierra Nevada Mountains in the northern and eastern portions of California; however, the plan area may increase or decrease somewhat over time due to the sale, purchase, or exchange of SPI lands (Service 2020, p. 7).

Sierra Pacific Industries manages their forestlands for the primary purpose of growing and harvesting timber. Some logging has occurred on all of SPI's lands and there is no old growth forest present. These forestlands are harvested using primarily even-aged silvicultural methods. Covered activities under the HCP include timber operations and other forest management activities. Major activities associated with the HCP include growing, harvesting, and transporting timber; timber stand regeneration and improvements; road and landing construction and maintenance; fuel break construction and maintenance; and monitoring and research (e.g., for spotted owls) (Service 2020, p. 8).

Implementation of the HCP is not expected to result in direct injury or mortality of CSO due to the implementation of conservation measures. To meet the HCP goals, SPI outlines eight conservation measures that will be implemented throughout the 50-year permit term. These measures include: increase aggregations of CSO habitat across the landscape; establish protection zones around all known and recently discovered activity centers; retain important habitat elements during salvage harvesting to accelerate the development of future habitat for spotted owls in sites that are reforested following salvage logging; reduce the risk of catastrophic fire by establishing fuel breaks and other fuel reductions strategies; conduct pre-operational surveys for spotted owls when conducting covered activities and protect active nests with a 0.25 acre buffer from March 15 to August 31; implement land access control activities and cooperate with local, state and federal law enforcement agencies to eradicate illegal marijuana plantations and prevent illegal firewood cutting that could remove habitat for the spotted owl or its prey; retain and manage habitat standards identified for spotted owl; and address barred owl expansion (Service 2020, pp. 10–13).

In 2015, SPI began studying barred owls via removal experiments. In 2018, the study was revised to include the following objectives: 1) assess the genetic differentiation of barred owl populations across northern and central California, 2) analyze allele frequency changes on the front of the range expansion, 3) estimate the amount of spotted owl – barred owl interbreeding (admixture) in each population, and 4) identify what barred owls are preying on in California. These efforts are ongoing and SPI has committed to continue these efforts during the term of the permit, as feasible. For more information about SPI's barred owl removal research, see 4.6 Competition and Hybridization with Barred Owls. Ongoing research and monitoring efforts for CSO on SPI land have indicated that some CSO populations in mixed-ownership landscapes have higher occupancy,

density, and probability of reproduction compared to CSO populations on public land (Roberts et al. 2017, p. 113; Hobart et al. 2019, p. 1987; [SPI] Sierra Pacific Industries et al. 2022, pp. 9, 17).

Western Riverside County Multiple Species Habitat Conservation Plan

The Western Riverside County Multiple Species Habitat Conservation Plan (MSHCP) is one of the largest habitat conservation plans in the United States covering 500,000 acres. Acreage includes 347,000 acres of public/quasi-public (PQP) lands that were conserved prior to the MSHCP, and 153,000 acres of Additional Reserve Lands that have been or will be acquired to complete the MSHCP. Collectively, 146 listed and unlisted species are Covered Species under the MSHCP, including CSO. The CSO is currently listed as a Species Not Adequately Conserved under the MSHCP until a Memorandum of Understanding (MOU) is executed with the U.S. Forest Service that addresses management of CSO on Forest Service lands. As of January 21, 2022, which was the latest update on the Status of Covered Species Not Adequately Conserved under the MSHCP, the MOU with the Forest Service had not yet been executed for CSO (https://www.wrc-rca.org/document-library/).

The MSHCP Plan Area includes 54,119 acres of modeled habitat for CSO. If the MOU with the Forest Service is signed, the loss of 12,905 acres (24%) of this modeled habitat is anticipated over the 75-year permit term. With the low density of CSO in the Plan Area, loss of these 12,905 acres is not anticipated to result in direct mortality of adult birds. However, loss of foraging and nesting habitats to development will cause CSO in impacted areas to disperse in search of other habitats. Birds forced to disperse may experience increased competition for the remaining suitable habitat or decreased fitness due to increased energy and time spent locating new habitats. They may also be subjected to increased rates of predation and injury. Further, if clearing of habitat occurs near the initiation of the breeding season, the search for and establishment of a new breeding site may result in an overall reduction in reproductive output. Thus, loss of breeding and foraging habitat may impact overall population numbers of CSO within the Plan Area over the long term by reducing the number of areas suitable for use as foraging and nesting sites (Service 2004, p. 449).

In order to offset these impacts, the MSHCP will conserve and manage 1,321 acres (2%) of modeled habitat for CSO within Additional Reserve Lands. Another 39,894 acres (74%) of modeled habitat will remain in PQP Lands. In total, 41,214 acres (76%) of the modeled habitat for CSO will be included in the MSHCP Conservation Area. If the MOU with the Forest Service is signed, additional monitoring and management would occur in habitat for CSO within Forest Service lands included in the MSHCP Conservation Area. Surveys for CSO will be conducted at least every eight years to verify occupancy at a minimum of 75% of the known and future-identified locations. If a decline in the distribution of CSO is documented below this threshold, management measures will be triggered, as appropriate, to meet the species-specific objectives identified in the MSHCP (Service 2004, p. 450).

Clean Air Act

The Clean Air Act of 1970 (42 U.S.C. 7401 et seq.) provides the platform for the Environmental Protection Agency (EPA) to develop and enforce regulations to protect the general

public from exposure to airborne contaminants known to be hazardous to human health. In 2007, the Supreme Court held that gases such as carbon dioxide fit within the Clean Air Act's definition of "air pollutant," and thus that EPA has the authority to regulate the emissions of such gases from new motor vehicles (Massachusetts *et al.* v. EPA, 549 U.S. 497, 532 (2007)).

California Fish and Game Codes

There are several California Fish and Game Codes that are relevant to the CSO. These codes limit take or destruction of CSO individuals and their nests. California Fish and Game Codes applicable to CSO, and their definitions, include:

> §355: "The commission may, annually, adopt regulations pertaining to migratory birds to conform with or to further restrict the rules and regulations prescribed pursuant to the Migratory Bird Treaty Act."
>
> §3503: "It is unlawful to take, possess, or needlessly destroy the nest or eggs of any bird, except as otherwise provided by this code or any regulation made pursuant thereto."
>
> §3503.5: "It is unlawful to take, possess, or destroy any birds in the orders Falconiformes or Strigiformes (birds-of-prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto."
>
> §3513: "It is unlawful to take or possess any migratory nongame bird as designated in the Migratory Bird Treaty Act or any part of such migratory nongame bird except as provided by rules and regulations adopted by the Secretary of the Interior under provisions of the Migratory Treaty Act."

California Species of Special Concern

California spotted owls are considered a California Species of Special Concern, designated by the CDFW, because declining population levels, limited ranges, and/or continuing threats have made them vulnerable to extinction (California Department of Fish and Wildlife, Natural Diversity Database 2018). The designation is administrative and does not carry formal legal status. However, the California Environmental Quality Act (CEQA; California Public Resources Code §§ 21000-21177) requires state agencies, local governments, and special districts to evaluate and disclose impacts from "projects" in the state. Section 15380 of the CEQA Guidelines clearly indicates that species of special concern should be included in an analysis of project impacts if they can be shown to meet the criteria of sensitivity outlined therein.

California Global Warming Solutions Act

The state of California passed Assembly Bill 32 (AB 32), the California Global Warming Solutions Act of 2006, to reduce the amount of greenhouse gas emissions within the state to 1990 levels by 2020. AB 32 requires the California Air Resources Board to adopt regulations for reporting and verifying statewide greenhouse gas emissions and for monitoring and enforcing compliance with the program.

Nevada Wildlife Codes

The Nevada Administrative Code (NAC) and Nevada Revised Statutes (NRS) contain several permanent regulations set forth by the Nevada Department of Wildlife (NDOW) that are relevant to CSO. These codes limit take, possession, or destruction of CSO individuals and their nests. Regulations applicable to CSO, and their definitions, include:

> NRS 503.585: A species or subspecies of native fish, wildlife and other fauna must be regarded as threatened with extinction when the Commission, after consultation with competent authorities, determines that its existence is endangered and its survival requires assistance because of overexploitation, disease or other factors or its habitat is threatened with destruction, drastic modification or severe curtailment. Any animal so declared to be threatened with extinction must be placed on the list of fully protected species, and no member of its kind may be captured, removed or destroyed at any time by any means except under special permit issued by the Department.
>
> NAC 503.050: Protected birds:
>
> 1. Are all species of wild birds protected by the Migratory Bird Treaty Act, as amended, 16 U.S.C. §§ 703 et seq., and listed in 50 C.F.R. § 10.13
>
> 2. Include the following species which are further classified as endangered:
>
> (c). California spotted owl (*Strix occidentalis occidentalis*)
>
> Applicable federal law is the Migratory Bird Treaty Act, as amended, 16 U.S.C. §§ 703 et seq. and federal regulations adopted pursuant thereto.
>
> NAC 503.090.1: There is no open season on those species of wild mammals, wild birds, fish, reptiles or amphibians classified as protected.
>
> NAC 503.093.1: A person shall not hunt or take any wildlife which is classified as protected, or possess any part thereof, without first obtaining the appropriate license, permit or written authorization from the Department.

Nevada Species of Conservation Priority

California spotted owls are considered a Nevada Species of Conservation Priority, designated by NDOW, because low numbers, limited availability of suitable habitat, uncertain population status, and threats such as improper forest management, catastrophic wildfire, and drought-related conifer mortality make them vulnerable to extinction within the state (NDOW 2022, Appendix E, pp. 96–98). The designation is administrative and does not carry formal legal status.

4.10 Potential Threats Not Carried Forward in Analysis

We also include a brief discussion here of potential influences to viability that were not carried forward within this SSA Report because there is either no evidence that the factors are negatively impacting the species, negative effects are expected to be minimal, or the known negative impacts are low and not having a population level impact. There is no evidence of overutilization of

the species for commercial or recreational purposes. There have been no documented changes in predator communities that would affect predation rates beyond those naturally experienced by CSO and we do not anticipate any changes in the future. Similarly, although there are known CSO parasites (including hematozoans, haemosporidians, and the flagellated protozoan parasite *Trichomonas gallinae*), and ectoparasites found on the species (including fleas, ticks, mites, and lice) (Gutiérrez 1989, p. 614; Hunter et al. 1994, p. 232; Ishak et al. 2008, p. 1; Rogers et al. 2016, p. 305), the expected current and future impacts from parasites are minor. There is limited information about disease impacts to the species: some hypotheses as to the impacts of parasites include reduced competitive advantage to barred owls due to infection and avian trichomonosis, a disease caused by a protozoan parasite that has caused mortality in other bird species (Ishak et al. 2008, p. 1; Rogers et al. 2016, pp. 305–306). Another disease of potential concern is West Nile Virus because it has had detrimental effects to other species of owls, including barred owls (Fitzgerald et al. 2003, pp. 602, 605; Komar 2003, pp. 190, 193, 195, 217–218, 223; Gancz et al. 2004, p. 2135; Nemeth et al. 2006, p. 2). However, there is currently no evidence West Nile Virus is having negative impacts on CSO (Hull et al. 2010, p. 168). There are some concerns that recreation within CSO habitat may cause degradation of habitat and behavioral disturbance, but little is known about this potential threat (LaHaye and Gutiérrez 2005, p. 204; Gutiérrez et al. 2017, pp. 217–218, 255). Northern spotted owls exposed to continuous traffic had higher corticosterone levels, a measure of physiological stress (Hayward et al. 2011, p. 1). Although Mexican spotted owl behavior activity budgets did not change markedly during a controlled hiking experiment, there was some evidence that high levels of recreational hiking could be detrimental (Swarthout and Steidl 2001, p. 312). In summary, over-utilization of the species for commercial or recreational purposes and predation are not discussed in the current condition and future condition sections of this SSA Report, although additional information could change this assessment in the future. Parasites, disease, and recreation are discussed in the future condition sections as we expect potential changes in these influences in the future. We will consider all threats in our summary of the species status now and in the future.

4.11 Interaction Between Threats

The threats discussed above not only act independently, but also interact with each other. It is important to assess the relationship between threats because there may be new or exacerbated impacts that are not considered when a threat is assessed alone. There are a vast number of ways threats may be interacting with each other, but the SSA Report will only focus on what is currently most relevant to the viability of the species. Figure 13 shows the relationships between threats, CSO habitat needs, CSO population needs, and ultimately CSO viability.

For example, climate change intensifies the threats of large-scale high-severity fire, drought, tree mortality, and increases interannual climate variability (Kadir et al. 2013, pp. 132, 137; Stephens et al. 2018, p. 77). Development in wildland-urban interfaces also increases the likelihood of large-scale high-severity fire (Mann et al. 2016, pp. 14–18). An increase of large-scale high-severity fires with changing climate conditions can lead to accelerated fire-facilitated conversion of forest edge to non-forested habitat (Parks et al. 2019, pp. 1, 7). The impacts to CSO would likely range from direct physiological impacts to indirect habitat and prey impacts. The loss of trees due to high-severity fire, drought, and tree mortality would likely lead to increased salvage logging on the landscape, further reducing CSO habitat. Additionally, the expansion of barred owls outcompeting CSO in

combination with timber harvest outside of PACs further worsens the outlook for habitat availability.

Where the different threats are occurring on the landscape simultaneously is also important to consider. Many of the threats are range-wide, but some may be more significant or more concentrated in particular parts of the range. Barred owls are moving south into the CSO range, so the northern portion of the Sierra Nevada will likely experience a greater magnitude of this threat, and earlier in time. Tree mortality is more concentrated in the Sierra Nevada than other parts of the landscape and may experience more significant impacts from this threat. The threat of wildfire in California has a higher likelihood in southern California than other portions of the CSO range. Considering the temporal, spatial, and interactive components of all the threats together is important for understanding the viability of CSO now and into the future.

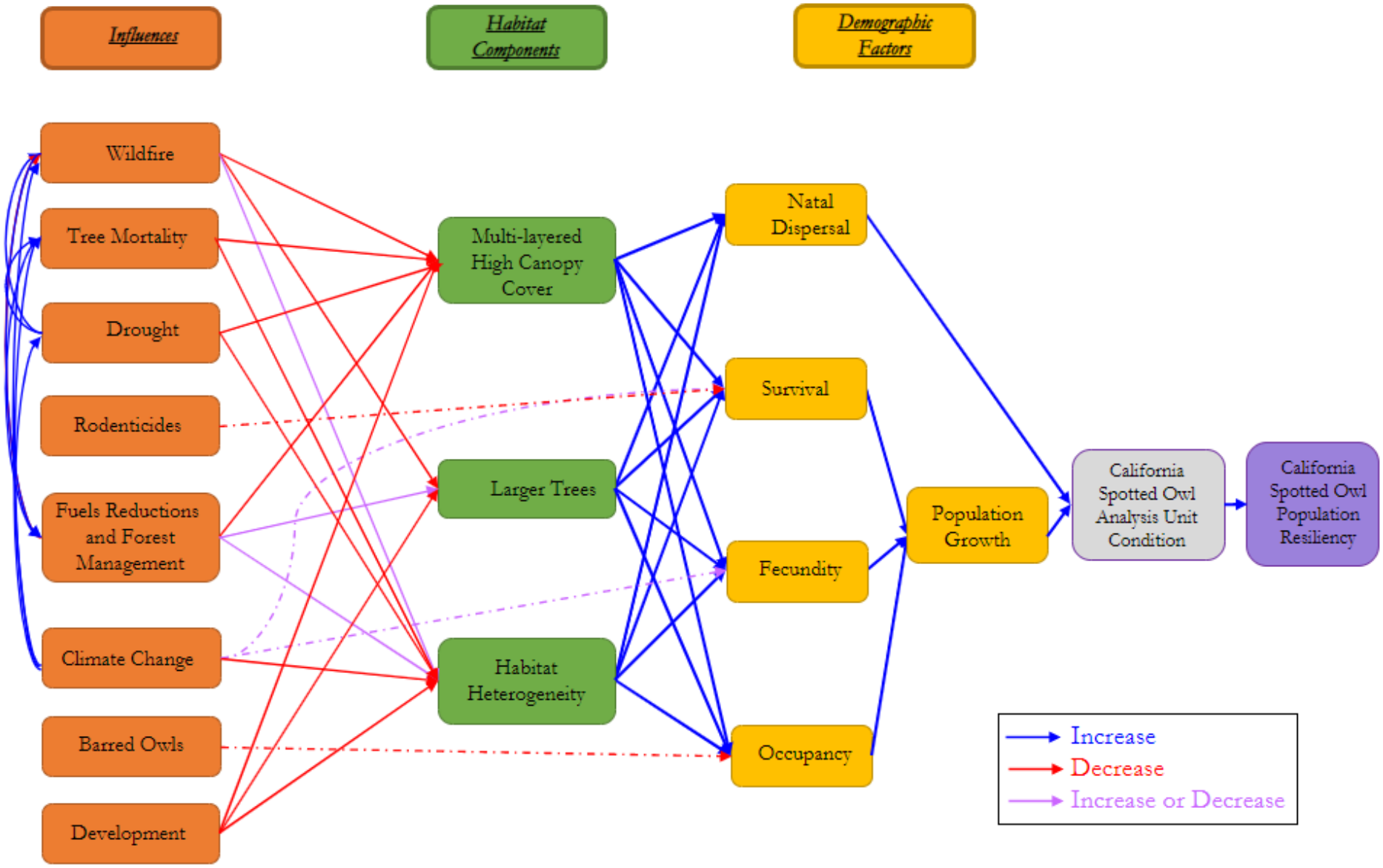


Figure 13: Conceptual model showing the interactions among influences, the species ecological needs, and how they interact to impact resiliency of California spotted owl populations. Blue arrows indicate a relationship where there is an increase; for example, an increase can mean one threat may increase or intensify the likelihood of another threat or an increase can mean that an individual need increases or promotes a population need. Red arrows indicate a decreasing relationship, where it can mean a decrease or reduction in the likelihood of another threat, or it can mean a decrease or reduction in an individual or population need. Purple arrows indicate that a threat may either increase (improve) or decrease (diminish) an individual or population need. Dotted lines indicate influences that not only impact habitat components, but also have direct impacts on demographic factor.

CHAPTER 5: CURRENT CONDITION

Current condition may be described in terms of past and ongoing changes in a species' habitat, demographics, and distribution (Smith et al. 2018, p. 306). To assess the current condition of CSO, we used the best scientific and commercial data available to analyze and describe, both quantitatively and qualitatively, past and ongoing changes in the species' habitat, demographic parameters, and distribution across the two populations and 15 analysis units described in Chapter 3 (see 3.2.1 Definition of a Population and an Analysis Unit). The methods and results of our assessment of current condition are described in the subsequent sections.

5.1 Current Condition Summary of Methods

For our current condition analysis, we consider two populations of CSO: one occupying the Sierra Nevada and the other coastal-southern California. To analyze these populations in more detail, we further divided them into analysis units; however, we recognize that these units do not function independently and in areas where the species distribution is continuous, like the Sierra Nevada, impacts to one unit may result in impacts to an adjacent unit. We assessed the condition of all CSO ecological needs where information was available for each analysis unit, including the demographic factors of survival, fecundity, occupancy, and population growth, and habitat components of large trees and canopy cover. In addition, because high-severity fire has significant effects on the condition of habitat within an analysis unit, we also incorporated results from our fire analysis in Chapter 4.1. For each population, we present an overview of the available information on ecological conditions and threats across the entire population, our analysis of the demographic factors and habitat components within each analysis unit to determine current condition, and a summary assessing population resiliency. We then assess CSO redundancy and representation under the current condition analysis. Additional information about our analysis of demographic and habitat condition is presented here.

To assess current condition, when available, we used demographic information available from partner reports and peer-reviewed literature. Researchers have been studying the demography of CSO in the Sierra Nevada since 1986. This research has focused on the Lassen National Forest, Eldorado National Forest, Sierra National Forest, and Sequoia/Kings Canyon National Parks. The San Bernardino National Forest in southern California was initially included, but mark-recapture studies there stopped in 1998. However, researchers have continued to collect occupancy and reproduction data within the San Bernardino analysis unit. These demography studies have provided consistent survival, fecundity, and occupancy data, and have been used to model occupancy and population growth changes in analysis units over time. For the analysis units that have been a part of demography studies, occupancy and population growth data were used to assess the current condition. Only one other analysis unit, Yosemite, had information available to assess occupancy, but the information is based on only three years of survey data, so we did not incorporate this information into our demographic analysis. Table 4 presents how we categorized the available demographic data to determine analysis unit demographic condition, with data presented as narrative for each analysis unit when available. Our assessment also discusses the amount of connectivity between analysis units.

Table 4: Demographic condition of analysis units.

Condition	Demographic data
Increasing	Increasing population trend over >10 years
Stable	Occupancy and/or population stable over >10 years, or increasing over <10 years
Declining	Occupancy reduced by up to 50% or population trend decreasing over >10 years
Strongly declining	CSO absent, or occupancy reduced by over 50% over >10 years
Unknown	No demographic data

For all analysis units, we also assessed current condition of an analysis unit using habitat components based on the assumption that high quality habitat supports stable or increasing populations and low quality habitat could only support declining or strongly declining populations. To assess current habitat condition, we looked at spatial information relevant to habitat components as well as information from our fire analysis described in Chapter 4.1. For large trees and multi-layered canopy cover we gathered optimal or normal values from a variety of resources, which are described below, and then conducted a quantitative habitat analysis calibrated using the known demographic information. We used updated Gradient Nearest Neighbor (GNN) forest structure maps (LEMMA 2020) for tree size from 2017. Plot data used to calculate all GNN habitat metrics ranged from 2000–2017 at a 30-meter resolution scale. These methods followed similar methods as (Jones et al. 2018, pp. 342–345). GNN data (including, but not limited to, large and medium trees with dense and medium cover) were also used to map habitat suitability for CSO across the Sierra Nevada (Keane in litt. 2022, p. 7). We used the attribute QMD_DOM, quadratic mean diameter of dominant and codominant trees in each pixel, to map tree size class. We defined large trees as >61 centimeters dbh. We also conducted an analysis specific to the coastal-southern California population assessing smaller size classes of hardwood and conifers because stick or platform nests are more common in this part of the range (LaHaye et al. 1997, pp. 42, 47); Tanner 2022, in litt.). We considered trees >33 centimeters dbh to evaluate the availability of trees that could potentially support a stick or platform nest. We used canopy cover data ("horizontal cover fraction occupied by tree canopies") from California Forest Observatory representing conditions on the ground in 2020 using satellite imagery at a 10-meter spatial resolution (Salo Sciences, Inc. 2020, pp. 1–3). We defined moderate canopy cover as >40% and did not use areas with <40% canopy cover in the analysis below. Further, because CSO in Yosemite National Park had territory centers with average values of 40% canopy cover in burned forests it further supports using this value to assess potential habitat (Schofield et al. 2020, pp. 4–5). We also calculated the area of overlap for each analysis unit between large trees and moderate canopy cover and incorporated the overlap values into our analysis. Because these sources use habitat data from earlier time periods, we removed areas that have burned at high-severity from fires that occurred after the time period represented by the available habitat data (e.g., areas that burned at high-severity in 2021 were excluded from the canopy cover dataset and areas that burned at high-severity after 2017 were excluded from the tree size dataset). Any fires that burned in 2022 were excluded from the dataset as the information was not available at the time this analysis was conducted (e.g., Oak and Washburn Fires near Yosemite National Park).

We used zonal statistics and tabulate area functions in ArcMap 10.8.1 to determine the proportion of large trees and moderate canopy cover within each CSO analysis unit. Proportions were calculated for the broad landscape scale of each analysis unit within the CSO range and within

the two CSO populations (Sierra Nevada and coastal-southern California). Results are shown in Table 5 (and by analysis unit in Tables 9 and 13 in the Sierra Nevada and coastal-southern California population sections 5.3.1 and 5.3.2). Maps showing the habitat components, including overlap, are presented in Figure 14. We also completed these calculations for the northern and southern Sierra Nevada as the northern Sierra Nevada tends to have more dense forests and higher precipitation, thus, resulting in potentially different CSO habitat conditions (Van Wagtendonk et al. 2006, p. 250; Climate Engine 2017). Tree mortality was also less severe in the northern Sierra Nevada (see Figure 9 in section 4.2 Tree Mortality). We considered the northern Sierra Nevada to include the Lassen, Plumas, Tahoe, Eldorado, and northern portion of the Humboldt-Toiyabe analysis units. The southern Sierra Nevada included the southern portion of the Humboldt-Toiyabe, Stanislaus, Yosemite, Sierra, Sequoia-Kings Canyon, Sequoia, and Inyo analysis units.

Table 5: Habitat component percentages for large trees and moderate canopy cover for the entire CSO range, the two CSO populations, and portions of the Sierra Nevada population.

CSO Population or Range	Large trees	Moderate Canopy cover
Range-wide	5%	46%
Sierra Nevada	7%	50%
Sierra Nevada North	5%	52%
Sierra Nevada South	9%	46%
Coastal-Southern California	1%	37%

Habitat condition within each analysis unit was assessed using different scoring systems depending on the habitat component being considered (see Table 6). For large trees and moderate canopy cover, we considered four separate categories to determine current condition, with less points assigned to decreasing habitat percentages. For our fire analysis, which is described in more detail in Chapter 4, we considered only two categories to determine current condition and we limited our analysis to high severity fires that have occurred between 2011–2021. To incorporate the fire information into our habitat analysis we only want to consider whether high-severity wildfires have had a negative impact to the overall unit. We consider high-severity wildfire values up to4% of the unit area to have a negative impact on the overall unit and assign those values -1 point to reflect their negative impact to habitat. High-severity wildfire values of 4% or less are assigned no point value.

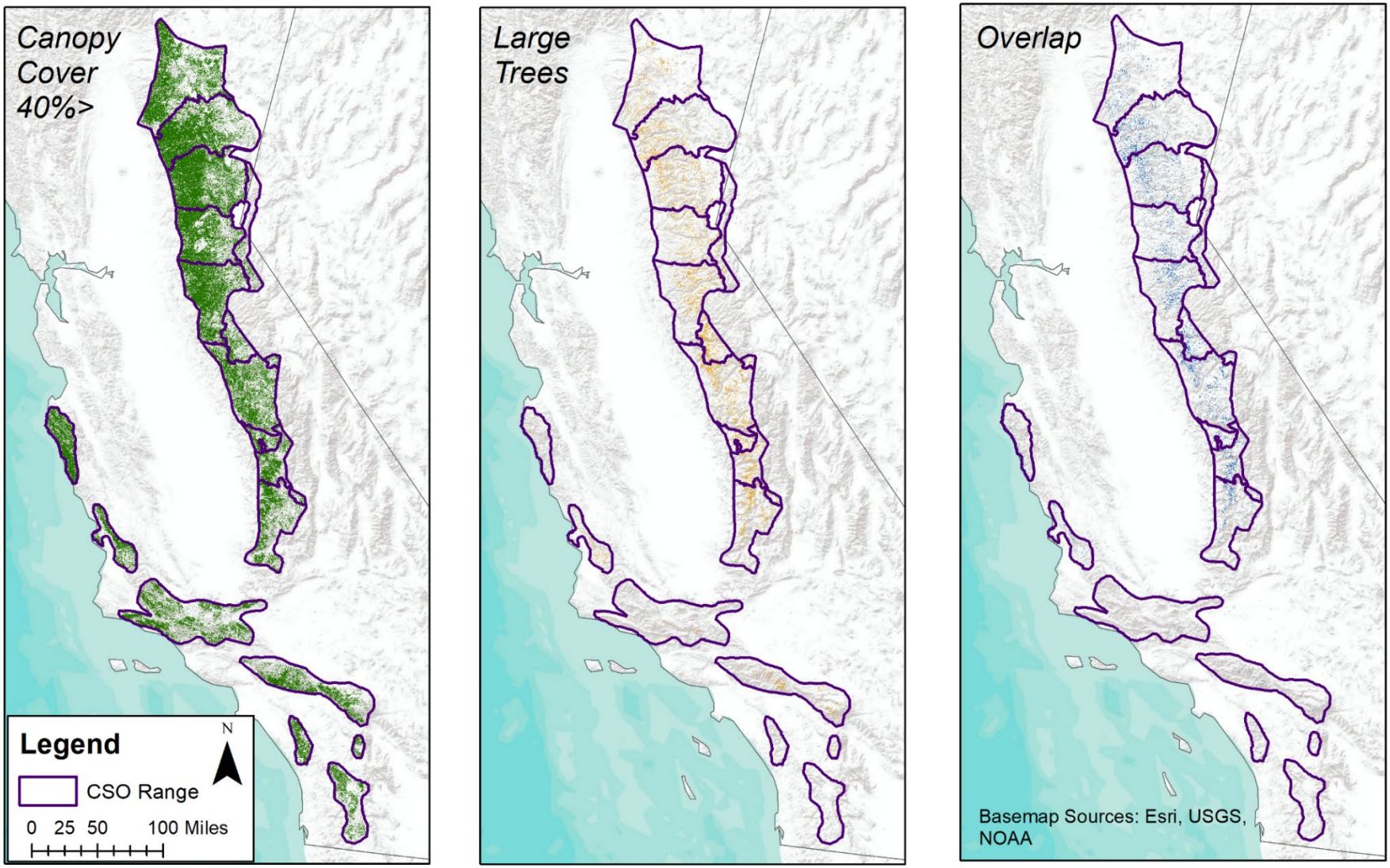


Figure 14: Moderate canopy cover, large trees, and the overlap between the two habitat needs in CSO range. Overlap values are presented by analysis unit in the Sierra Nevada and coastal-southern California population sections 5.3.1 and 5.3.2.

Table 6: Summary of habitat component scoring for large trees, high canopy cover, moderate canopy cover, and the proportion of the analysis unit burned at high-severity.

Score	Large Trees	Moderate Canopy Cover	Large Trees and Moderate Canopy Cover	Proportion burned at high-severity (2011-2021)
3	>15%	>60%	--	--
2	10-15%	41-59%	--	--
1	2-9%	27-40%	>7%	--
0	<2%	0-26%	0-6%	0-4%
-1	--	--	--	>4%

We add the scores across each of the four categories to assign a habitat condition for each analysis unit. We used the available demographic information to help calibrate our habitat assessment, and then used the results of our habitat analysis to determine analysis unit condition. Analysis units with final habitat scores of 6–7 were considered to have the highest habitat suitability, units with habitat scores of 4–5 were considered to have suitable habitat, scores of 2–3 were considered to have less suitable habitat, and units with scores of 0–10 are considered to have the lowest suitability. If an additive score for an analysis unit was -1, we would consider that unit to have no habitat suitability (see Table 7). Note that the individual scores of each habitat component are not associated with overall condition (e.g., an analysis unit with moderate canopy cover above 30% would have 1 point added to habitat condition score, but it does not necessarily mean that the analysis unit is in low or declining condition, and an analysis unit that was >4% burned at high-severity between 2011 and 2021 is not necessarily in declining condition or extirpated, but the condition of the habitat would have been reduced from that burn). We also incorporated overlap values between moderate canopy cover and large trees in our scoring. Although values were low across all analysis units., these findings are consistent with those from other habitat analyses for CSO (e.g., Table 1 in Jones et al. 2018, p. 5) and reinforce the complexity of assessing CSO habitat. The threat of barred owls is not considered in the analysis of current condition because of the success of recent and aggressive removal experiments as described in Chapter 4.6, but is considered in the future as described in the next chapter because of evidence documenting their ability to recolonize and expand rapidly.

Table 7: Habitat analysis based on adding habitat component scores across an analysis unit.

Habitat Score	Habitat Suitability	Overall Condition
-1	No suitability	Extirpated
0–1	Lowest suitability	Strongly Declining
2–3	Less suitable	Declining
4–5	Suitable	Stable
6–7	Highest suitability	Increasing

If demographic data are available for an analysis unit, we provide both the demographic condition as presented in Table 4 and the habitat analysis results to describe the current condition for that analysis unit. For analysis units where no demographic data are available, or where demographic data are only available for a small section of the area within that unit, we only present

our habitat analysis to describe current condition. Our habitat analysis will be used in the assessments of future condition in Chapter 6.

As mentioned in the previous paragraph, we took the average of habitat scores for all analysis units within a population to determine a population score and corresponding population condition; population condition is compared to population resiliency in Table 8. For populations that have an increasing condition, we expect them to have high resiliency at that time period (i.e., they have stable or increasing survival, fecundity, and occupancy, and available habitat has high suitability and is well connected). Populations in increasing condition are expected to persist into the future and have the ability to withstand stochastic events that may occur. Populations in stable condition, which are less resilient than those in high condition, are expected to maintain moderate resiliency with the majority (approximately 70–90 percent) of these populations expected to persist beyond 40–50 years. Populations in stable condition may have some declines in individual or population needs but would likely still be able to support a population. Using this definition, we would not consider a population with very low numbers of individuals, even if those low numbers were stable, to be in stable condition. Because the numbers being maintained are at a very low abundance, we would consider this population to be in declining condition. Populations in declining condition have low resiliency and may not be able to withstand stochastic events because of significant declines in occupancy, survival, fecundity, or habitat suitability. Populations with a declining condition are less likely to persist for 40–50 years, but a population in a declining condition does not automatically mean it will become extirpated. Populations that have a strongly declining condition have very low resiliency and are likely not to withstand stochastic events because of significant declines in occupancy, survival, fecundity, or habitat suitability. Populations in strongly declining condition may not persist for 40–50 years and have the potential to be extirpated. Populations in extirpated condition will not persist for 40–50 years. Populations that have an extirpated condition have no resiliency and cannot withstand stochastic events. To assess the current condition of redundancy we consider the size and distribution of the two CSO populations throughout the species' range, and the plausible catastrophic events to which the species may be exposed. To assess the current condition of representation, we consider the ecological setting and genetic diversity among the two populations.

Table 8: Population condition based on averaging scores across analysis units within a population and how population condition relates to population resiliency

Population Score	Population Condition	Resiliency Definition
<0	Extirpated	None
0–1	Strongly declining	Very Low
2–3	Declining	Low
4–5	Stable	Moderate
6–7	Increasing	High

5.2 Current Condition Uncertainty

We do not have an estimate of CSO abundance throughout the range of the species. Historically the number of CSO territories was used as an index to illustrate the range of the species

and areas in which it occurs. This number includes PACs and other estimates of territories available in the literature. It is a cumulative total of all territories known to be historically or currently occupied by at least one CSO through 2002, so the total increased over time as CSO moved to new territories and as researchers surveyed new areas. Because the number of historical CSO territories was additive rather than reflective of current occupancy, and is outdated by 20 years, these data do not accurately reflect current condition for the species, and should not be viewed as a current population estimate for the taxon. For PACs specifically, they are only retired when the habitat is no longer suitable (i.e., due to wildfire) or they have been reliably documented to lack occupancy or breeding activity in consecutive recent years (Forest Service 2019b, p. 27). Many territories with sufficient suitable habitat may not be occupied in the years following their initial discovery and some historical territories may no longer have sufficient suitable habitat to support CSO due to logging or fires. Moreover, the most recent number of CSO territories was last updated in 2002; since that time, we have not received updated estimates of the total number of territories range-wide. At that time, a total of 2,306 CSO territories had been documented, 1,865 (81%) of which are in the Sierra Nevada (71 FR 29886). Most territories are monitored opportunistically as funding or specific projects arise (e.g., timber harvest project, fuels reduction project, post-fire monitoring, etc.), so without a systematic survey effort, it is challenging to determine the exact number of CSO territories.

While there are extensive and detailed data for many CSO analysis units, not all analysis units have demographic information available to analyze the demographic conditions of occupancy, survival, and fecundity. Additionally, optimal values for large tree and multi-layered moderate canopy cover conditions were largely based upon values from the Sierra Nevada. These values could be different for the coastal-southern California population analysis units, but very little data are available to make this comparison (although we did incorporate an additional analysis using smaller trees for coastal-southern California, as described in the section above). There are limitations to using both GNN and California Forest Observatory data layers to map current CSO habitat conditions, including the scale of analysis and changes in habitat since the layers were published. We attempted to account for some of these changes in habitat by removing areas that have experienced high-severity wildfire since the data layers were published. The scale at which these habitat data are most relevant is larger than the scale at which CSO select nest or roost sites, and the characteristics at the nest tree itself are likely the most important. For example, canopy cover at a nest tree could be due solely to the clumping of several large trees and thus be considered very high at the nest tree, but this detail is lost when the available data are averaged at a larger spatial resolution. We also acknowledge that the presence of a large tree alone (or the smaller tree sizes specific to coastal-southern California) does not ensure that CSO will initiate nesting. Platform and stick nests are often created and abandoned by other wildlife species or features associated with the tree like mistletoe brooms, which we are unable to measure with the data available for this SSA Report. However, there are likely other changes in habitat that have also not been accounted for in our analysis. Although using our habitat analysis as a proxy for condition when demographic information is unavailable leaves the possibility of underestimating or overestimating condition, we think that using the presence of habitat features (large trees and canopy cover) is more likely to overestimate condition by assuming CSO presence in potential habitat. Further, we used the available demographic information to calibrate the categories for our habitat analysis. It is unlikely

that CSO in numbers that might constitute a stable or increasing population in any of the analysis units for which we do not have demographic data have gone undetected by community science (i.e., eBird data), which we would have uncovered while searching available data. Even if we are underestimating habitat due to the scale of our analysis not picking up enough canopy cover, we still cannot assume CSO presence. Further, specific to the coastal-southern California population, available literature (Gutiérrez et al. 2017, p. 242; Tempel et al. 2022, pp. 20–21) suggests that demographics in areas without recent survey data are reduced compared to those with demographic information.

The Geographic Distribution section (Chapter 2.3) of this SSA Report describes available information about potential CSO occurrences in Baja California Norte, Mexico, and the reasons for considering CSO to be only a rare visitor of this area and for not including these areas as part of the species range. However, we acknowledge the uncertainty surrounding CSO in Baja and the lack of information on CSO habitat and/or breeding status in this area. Updated information could change our understanding of the species range to include additional areas besides those currently described in this SSA Report.

5.3 Current Analysis Unit Condition and Population Resiliency

5.3.1 Sierra Nevada Population

Until recently, CSO and suitable habitat were relatively well-distributed in the Sierra Nevada with few barriers to dispersal (Gutiérrez et al. 2017, p. 94): as of 2017, an estimated 1.98 million hectares (4.9 million acres) of suitable habitat for CSO was available in the Sierra Nevada, primarily on federal lands (Gutiérrez et al. 2017, pp. xx, 123). Of that land, 75% is managed by the Forest Service, 7% is managed by the National Park Service (Park Service), and 18% is either privately owned or managed by other government agencies (Gutiérrez et al. 2017, p. xx). The suitable habitat in Gutiérrez et al. (2017) was determined using the California wildlife habitat relationships existing vegetation classification and mapping using tree size classified as ≥ 30 cm (12 in) in combination with canopy cover ≥40%. However, recent large, catastrophic fires have reduced available habitat and have likely created new barriers for CSO dispersal (see Chapter 4.1 Wildfire). Other barriers to dispersal include urban and suburban development, large reservoirs, physiographic features such as non-forested or unsuitable habitat or vegetation communities, or lack of riparian areas to act as corridors through unsuitable extents (Gutiérrez et al. 2017, pp. 94–95, 253–254). Specific information about habitat and demographic conditions, when available, is incorporated below for each of the Sierra Nevada analysis units.

From our habitat analyses, we found that the Sierra Nevada has higher canopy cover and tree size values than coastal-southern California, which was not unexpected (see Tables 5, 9, and 13). When comparing the northern to the southern Sierra Nevada, the north contains higher canopy cover which aligns with historical forest structure data that tends to show more dense forests in the northern Sierra Nevada (Van Wagtendonk et al. 2006, p. 250), with the exception being are on the east side of the Sierra Nevada (i.e., Humboldt-Toiyabe and Inyo analysis units) which contain more open and disjunct habitat than the west side. Higher canopy cover combined with higher precipitation levels tend to result in lower tree mortality in the northern Sierra Nevada (see Figure 9 in section 4.2 Tree Mortality) which may have helped reduce the potential for megafires in the

northern Sierra Nevada in past years, but climate change impacts of reduced snowpack and increased temperatures show that increased fire risk is also occurring in the northern Sierra Nevada (see 4.4 Climate Change). We also found the two units mostly containing National Parks (e.g., Yosemite and Sequoia-Kings Canyon) contain the largest tree size percentages. Overall, the overlap values between canopy cover and large trees was low across all analysis units (see Table 9)

Table 9: Habitat component (large trees, moderate canopy cover, and their overlap) analysis results for analysis units within the Sierra Nevada population.

Analysis Unit	Large trees	Moderate Canopy cover	Moderate Canopy Cover & Large Trees Overlap
Lassen	4%	48%	2%
Plumas	5%	51%	4%
Tahoe	7%	64%	5%
Eldorado	6%	57%	4%
Humboldt-Toiyabe	4%	24%	2%
Stanislaus	7%	62%	5%
Yosemite	18%	36%	9%
Sierra	9%	47%	6%
Sequoia-Kings Canyon	11%	44%	8%
Sequoia	7%	37%	3%
Inyo	7%	26%	3%

The threats that are currently impacting the Sierra Nevada population include large-scale high-severity fire, tree mortality, drought, climate change, various impacts from fuels reductions and forest management, competition with barred owls, and rodenticides. As described in the descriptions of the analysis units below, these threats are not equivalent across all analysis units within the Sierra Nevada population. For example, competition with barred owls is more pronounced in the northern part of this population than in the southern portion, and the threat from rodenticides is more pronounced at the wildlife-urban interface. However, some threats, like fire, are considered a threat across the population, and there is a general increasing trend in the annual acreage and relative proportion of high-severity fires in the Sierra Nevada (Keane in litt. 2022, p. 3). In 2020–2021, the percent of habitat that burned at high-severity within CSO PACs in the Sierra Nevada was almost twice as that from 1993–2019; in 1993–2019, 35% of fire burned at high-severity, compared to 65% of fire being high-severity in 2020–2021. (Keane in litt. 2022, p. 5). We conducted a separate fire analysis for the entire CSO range which includes PACs as well as additional acreage outside PACs. Our fire analysis shows similar results, with approximately 42% of the CSO range in the Sierra Nevada burned between 1984 and 2021, with 7% and 12% of that total from acreages burned in 2020 and 2021, respectively. Of the 42% of CSO range burned within the Sierra Nevada, approximately 13% was burned at high-severity. In our supplemental analysis which analyzes habitat and fire metrics along a documented ecological boundary between the northern and southern Sierra Nevada, we found that both portions of the Sierra Nevada burned at similar amounts between 1984 and 2021. However, the majority of burned acreage in the northern Sierra Nevada occurred in 2021 (18% burned with 9% at high-severity compared to 5% or less in all other years and 2% or less for

high-severity from 1984 to 2021). In the southern Sierra Nevada 11% burned in 2020 with 2% at high-severity in 2020 and 2021, compared to 5% or less total burned and 1% or less for high-severity from 1984 to 2021. These results are presented in Appendix I and suggest higher levels of disturbance to the species and increased recovery time for habitat conditions to improve post-fire because such a large acreage burned over a relatively concentrated period of time. Fire severity information by analysis unit is described below for each of our Sierra Nevada analysis units from 1984 through 2021 and is shown in Table 10. Data from 2011 through 2021 is shown in Table 11 (see Appendix I for tables of fire severity by year for each analysis unit).

Table 10: Proportion of analysis unit burned at low-, moderate-, and high-severity for the Sierra Nevada analysis units from 1984 to 2021.

Analysis Unit	Low-Severity	Moderate-Severity	High-Severity	Total
Lassen	15.63%	11.65%	16.29%	43.57%
Plumas	20.63%	19.51%	30.92%	71.06%
Tahoe	2.97%	2.70%	2.64%	8.31%
Eldorado	9.57%	7.84%	13.85%	31.26%
Humboldt-Toiyabe	5.42%	5.22%	5.66%	16.30%
Stanislaus	14.80%	14.23%	9.35%	38.38%
Yosemite	32.88%	14.80%	8.93%	56.61%
Sierra	21.07%	15.24%	7.27%	43.58%
Sequoia-Kings Canyon	16.70%	8.44%	6.85%	31.99%
Sequoia	24.32%	19.47%	16.41%	60.20%
Inyo	18.34%	10.91%	7.11%	36.36%

Table 11: Proportion of analysis unit burned at low-, moderate-, and high-severity for the Sierra Nevada analysis units from 2011 to 2021.

Analysis Unit	Low-Severity	Moderate-Severity	High-Severity	Total
Lassen	10.89%	8.61%	13.58%	33.0%
Plumas	14.72%	15.03%	26.89%	56.34%
Tahoe	0.74%	0.76%	0.59%	2.09%
Eldorado	8.33%	6.47%	11.85%	26.65%
Humboldt-Toiyabe	2.45%	2.21%	3.83%	8.49%
Stanislaus	7.60%	7.41%	5.10%	20.11%
Yosemite	13.58%	8.14%	4.93%	26.65%
Sierra	18.24%	13.28%	6.52%	38.04%
Sequoia-Kings Canyon	10.15%	5.55%	5.66%	21.36%
Sequoia	15.05%	11.77%	10.29%	37.11%
Inyo	8.01%	4.45%	0.49%	12.95%

In addition to common threats acting on all analysis units within this population, there are also common management actions taking place within the Sierra Nevada. For example, the Forest

Service designates PACs around known CSO nest trees, so analysis units containing national forests (e.g., all Sierra Nevada population analysis units except for Yosemite and Sequoia-Kings Canyon) include these protections (see 4.9 Regulatory Mechanisms and Management Actions). Further, barred owl removal experiments have so far been successful in avoiding the catastrophic impacts that could have occurred in the absence of any management (see 4.6 Competition and Hybridization with Barred Owls and 4.9 Regulatory Mechanisms and Management Actions).

Lassen Analysis Unit Condition

The Lassen analysis unit includes the Lassen National Forest, Lassen National Park, and other private lands that are within the CSO range. Forest Service lands and Park Service lands were combined within this one analysis unit due to the fact that Lassen National Park is completely surrounded by and within Lassen National Forest.

The Lassen analysis unit has been part of an ongoing CSO demography study, with consistent data ranging back to the early 1990s (Jones et al. 2018, p. entire); most of the area within this study is on public land managed by the Forest Service. This analysis unit has high apparent adult survival (Blakesley et al. 2010, pp. 13–14; Conner et al. 2016, p. 11). Blakesley et al. (2010, p. 12) found male adult survival in the Lassen analysis unit to be 0.840 (± 0.017) and female adult survival to be 0.848 (±0.016). Reproductive output, measured in both number of female young fledged per territorial female and total number of young fledged per territorial female, have varied over time (Franklin et al. 2004, p. 24; Blakesley et al. 2010, pp. 17–19). Models of the probability of territory occupancy show reductions of 21% (95% Confidence Interval -34% to -9%) from 1993 to 2013 (Conner et al. 2016, p. 15). When taking into account all demographic parameters, a population decline of -44% has been observed (95% Confidence Intervals -61% to -21%) over that same time period (Conner et al. 2016, p. 15).

Our habitat analysis found the Lassen analysis unit contains 4% large trees, a moderate canopy cover value of 48%, and a large tree and moderate canopy cover overlap value of 2%. Although this unit has a relatively high canopy cover percentage compared to other analysis units within the Sierra Nevada population, the low percentage of large trees suggests the habitat has been degraded from historical conditions. Our fire analysis supports this, with approximately 44% of the unit burned between 1984 and 2021, 16% of which was at high-severity. Between 2011 and 2021, 14% of the unit burned at high-severity. Protected Activity Center data from the Forest Service from 1993–2021 reveals wildfires have burned 57% of PAC acreage in the Lassen National Forest, which is part of the Lassen analysis unit. Wildfires have burned 62% of PAC acres within fire perimeters at high- or moderate-severity (Keane in litt. 2022, p. 6). Most recently, the Dixie fire burned almost 850,000 acres, including habitat containing 168 PACs (Keane in litt. 2022, p. 13).

Current condition for the Lassen analysis unit was determined using available demographic information and our habitat analysis. Our habitat analysis found this unit has less suitable habitat with an overall score of 2. Considering population declines through 2013 and substantial reduction in habitat from wildfire within this analysis unit, the current condition of the Lassen analysis unit is declining (see Table 12).

Plumas Analysis Unit Condition

The Plumas analysis unit includes the Plumas National Forest as well as private lands in the area within the CSO range. The CSO demography study described for the Lassen unit also covers a large portion of the Plumas analysis unit; therefore the results of that demographic study (i.e., survival, fecundity, occupancy, or population growth) also applies to the Plumas unit.

For the Plumas analysis unit, our habitat analysis found the unit contains 5% large trees, 51% moderate canopy cover, and a large tree and moderate canopy cover value of 4%. Similar to the Lassen unit, the Plumas unit has a relatively high canopy cover percentage, but a low percentage of large trees, suggesting the habitat has been degraded from historical conditions. Since our fire analysis reveals approximately 71% of this analysis unit has burned between 1984 and 2021, 31% at high-severity, the habitat condition of this unit has been degraded since historical conditions. Further, 27% of the unit has burned at high severity between 2011 and 2021.

Between 1993 and 2021, wildfires have burned 65% of PAC acreage in the Plumas National Forest portion of this analysis unit. Considering only PAC acres within fire perimeters, wildfires have burned 68% at high or moderate-severity during this same time period (Keane in litt. 2022, p. 6). Available suitable habitat has decreased from over 303,000 ha (pre-2017) to under 200,000 ha in 2022 (removing areas burned with 50% basal area mortality) (Chudek in litt. 2022, p. 2). These wildfires have affected many PACs in the Plumas National Forest, in some cases resulting in complete habitat loss or retirement of the PAC designation, and in other cases leading to minor to significant boundary revisions of the PACs (Chudek in litt. 2022, p. 1). Since 2000, 177 out 319 PACs have had a change in status or boundary: 55 have been retired (all but 1 of these due to wildfires), an additional 20 pending retirement, and 102 PAC boundaries have been revised. Border revisions may remain within fire scars and revisions may be redrawn in areas with lower quality or degraded habitat in areas burned at lower-severity. In some cases, PACs were redrawn into areas with no previous history of CSO use (Chudek in litt 2022, p. 2). Wildfire effects to CSO in the Plumas National Forest have accelerated between 1993 and 2021, and wildfires have impacted 146 PACs in the last three years alone (Chudek in litt. 2022, p. 1). A gap in the distribution within the Plumas analysis unit, mainly on private land, extends east-west which may limit dispersal within this analysis unit (Gutiérrez et al. 2017, pp. 204–206).

Our habitat analysis found this unit has less suitable habitat with an overall score of 2. Overall, the current condition of the Plumas analysis unit is declining based on available demographic information and our habitat analysis, which is further supported by available information on PAC retirement and PAC boundary revisions (see Table 12).

Tahoe Analysis Unit Condition

The Tahoe analysis unit includes the Tahoe National Forest, a portion of the Forest Service's Lake Tahoe Basin Management Unit, as well as private lands in the area within the CSO range. No information is available to assess the current condition of survival, fecundity, occupancy, or population growth for the Tahoe analysis unit.

The results of our habitat analysis for the Tahoe analysis unit found the unit contains 7% large trees, 64% moderate canopy cover, and 5% overlap of large trees and canopy cover. This unit

has the highest canopy cover percentage; however, the results for tree size suggest the habitat has been degraded from historical conditions. In contrast, our fire analysis finds only 8% of this unit has burned between 1984 and 2021, with only 3% at high-severity, suggesting the habitat in this unit is likely still relatively intact. Between 2011 and 2021, only 1% of this unit burned at high severity. From 1993–2021, wildfires have burned 13% of PAC acreage in the Tahoe National Forest, part of this analysis unit. Considering only PAC acres within fire perimeters, wildfires have burned 46% at high- or moderate-severity (Keane in litt. 2022, p. 6). Granite outcrops and red fir forest, both associated with low CSO density, give the habitat a checkerboard pattern of suitability which may limit CSO distribution within the analysis unit causing Verner et al. (1992, pp. 49–50) to label this an area of concern for the integrity of the range within the Sierra Nevada (Gutiérrez et al. 2017, pp. 204–206).

Our habitat analysis found this unit has suitable habitat with an overall habitat suitability score of 4. Overall, the current condition of the Tahoe analysis unit is stable based on our habitat analysis (see Table 12).

Eldorado Analysis Unit Condition

The Eldorado analysis unit includes the Eldorado National Forest, a portion of the Lake Tahoe Basin Management Unit, as well as other private lands in the area within the CSO range. The Eldorado analysis unit has been part of an ongoing demography study within the CSO range, with data ranging back to the early 1990s (Jones et al. 2018, p. entire); most of the area within this study was on public land managed by the U.S. Forest Service. This analysis unit has high apparent adult survival (Blakesley et al. 2010, pp. 13–14; Tempel et al. 2014b, p. 91). Blakesley et al. (2010, p. 12) found male adult survival in the Eldorado analysis unit to be 0.843 (± 0.020) and female adult survival to be 0.811 (±0.021). Reproductive output has a decreasing trend (Franklin et al. 2004, p. 24; Blakesley et al. 2010, pp. 17–19). When only considering occupancy from 1993–2010, population declines have been modeled to be -30% (95% Confidence Interval -45% to -15%) (Tempel and Gutiérrez 2013, pp. 1091–1093). A follow-up study using an integrated population model (which took into account all demographic parameters, including occupancy data, reproduction data, and mark-recapture data) calculated a population decline of 50% (95% CI: -62% to -46%) from 1990–2012 (Tempel et al. 2014b, pp. 86, 90–92). A checkerboard pattern of lands and large private inholdings may limit distribution across this analysis unit; the checkerboard pattern of lands is associated with mixed habitat suitability, and lack of surveys on private lands (and therefore uncertainty about presence) also led Verner et al. (1992, pp. 49–50) to label this an area of concern (Gutiérrez et al. 2017, pp. 204–206).

Habitat values for this unit includes 6% large trees, 57% moderate canopy cover, and 4% overlap of large trees and canopy cover. These data suggest that the habitat is degraded. Our fire analysis finds between 1984 and 2021, 31% of this unit has burned, 14% at high-severity, and between 2011 and 2021 12% of the unit burned at high severity. From 1993–2021, wildfires have burned 57% of PAC acreage in the Eldorado National Forest, part of this analysis unit. Considering only PAC acres within fire perimeters, wildfires have burned 62% at high or moderate-severity (Keane in litt. 2022, p. 6). When considering the Caldor Fire that burned in 2021, 43.8% of PACs burned at over 50% high severity (Keane in litt. 2022, p. 13).

Our habitat analysis found this unit has less suitable habitat with an overall habitat suitability score of 2. Considering demographic information and our habitat analysis for this analysis unit, the current condition of the Eldorado analysis unit is declining (see Table 12).

Humboldt-Toiyabe Analysis Unit Condition

The Humboldt-Toiyabe analysis unit is a small analysis unit on the eastern edge of the CSO range that includes a portion of the Humboldt-Toiyabe National Forest, a portion of the Lake Tahoe Basin Management Unit, as well as state and private lands in the area within the CSO range. There are six PACs within the Humboldt-Toiyabe National Forest, most of which have experienced impacts from threats and reduced detections in recent years. The only confirmed active PAC was fully consumed by wildfire in 2021 (Forest Service 2022d). One CSO territory currently exists on state land at Lake Tahoe and has been active every year since it was first discovered in 2015. The territory has fledged 3 young during that time (Enders in litt. 2022). There are no PACs in the Lake Tahoe Basin Management Unit within this analysis unit. No further information is available to assess the current condition of survival or fecundity, for the Humboldt-Toiyabe analysis unit. There are no known barriers to limit dispersal within this analysis unit.

Habitat analysis for this unit only included habitat within California because there were no data available for Nevada that was comparable to the data for California used for the rest of this SSA Report., The results of our habitat analysis for this unit found 4% large trees, 24% moderate canopy cover, and a large trees and moderate canopy cover overlap value of 2%. These results suggest the habitat is less suitable for CSO, possibly due to a less productive system on the eastern edge of the Sierra Nevada (Dilts 2022, p. 5). For the northern and eastern portion of this analysis unit, which cover some of the Nevada extent not included in our habitat analysis, Dilts (2022, pp. 5–9) found that habitat for both nesting and foraging is extremely limited and more discontinuous compared to other parts of the Sierra Nevada including within the Lake Tahoe Basin.

Our fire analysis finds that between 1984 and 2021, 16% of the unit has burned with 6% of this at high-severity, which is relatively low compared to the other Sierra Nevada analysis units. Between 2011 and 2021, only 4% of the unit burned at high severity. However, in 2021, 2 of the 6 PACs on the Humboldt Toiyabe National Forest were partially or fully consumed by the Tamarack Fire (Forest Service 2022d, pp. 2–3).

Our habitat analysis found this unit has the lowest habitat suitability with an overall score of 1, which is at the upper limit of our scoring boundary for this habitat suitability category. Overall, the current condition of the Humboldt-Toiyabe analysis unit is strongly declining based on available PAC information and our habitat analysis (see Table 12).

Stanislaus Analysis Unit Condition

The Stanislaus analysis unit includes the Stanislaus National Forest as well as private lands in the area within the CSO range. No information is available to assess the current condition of survival, fecundity, or occupancy for the Stanislaus analysis unit. Dispersal may be constrained by two potential gaps in the distribution because of large private inholdings, where occupancy is unknown, and a burned area leaving the habitat highly fragmented (Verner et al. 1992, pp. 49–50; Gutiérrez et al. 2017, pp. 204–206).

This unit contains 7% large trees, 62% moderate canopy cover, and 5% overlap of large trees and moderate canopy cover based on the results of our habitat analysis. Between 1984 and 2021, approximately 38% of the unit has burned, with 9% at high-severity. Between 2011 and 2021, 5% of the unit burned at high severity. These values suggest some habitat degradation has occurred in this unit since historical conditions. From 1993–2021, wildfires have burned 36% of PAC acreage in the Stanislaus National Forest, which is part of this analysis unit. Considering only PAC acres within fire perimeters, wildfires have burned 43% at high- or moderate- severity (Keane in litt. 2022, p. 6).

Our habitat analysis found this unit has less suitable habitat with an overall habitat suitability score of 3, which is at the upper limit of our scoring boundary for this habitat suitability category. Overall, the current condition of the Stanislaus analysis unit is declining based on our habitat analysis (see Table 12).

Yosemite Analysis Unit Condition

The Yosemite analysis unit includes Yosemite National Park as well as private lands in the area within the CSO range. Based on data collected recently within Yosemite National Park, 36 historical CSO territories from 2004 and 2013 were monitored from 2015 through 2017 and 27 territories were documented (Schofield et al. 2020, pp. 2, 3, 5). Several nests were found in 2017, including eight nests within the 2013 Rim Fire perimeter and eight nests outside the perimeter (Schofield et al. 2020, p. 5), indicating occupancy and fecundity may have remained stable and largely unaffected by the Rim Fire and drought. Because the Yosemite analysis unit does not have the 20+ years of data that are available for the other analysis units that are part of the CSO demography study, it is hard to compare across timescale and protocols. There are no known barriers which may limit dispersal in this area.

Our habitat analysis found the Yosemite analysis unit contains 18% large trees, 36% moderate canopy cover, and an overlap value of 9%. Although this unit has a relatively low percentage of moderate canopy cover compared to other analysis units in this population, the high percentage of large trees suggests the habitat is not as degraded as other Sierra Nevada population units. Our fire analysis finds approximately 57% of the unit burned between 1984 and 2021, 9% of which was at high-severity. Between 2011 and 2021, 5% of the unit burned at high severity.

Although CSO in Yosemite were detected successfully reproducing using moderate canopy cover values, they may have been successful due to the presence of large trees in this analysis unit and overall high quality habitat prior to disturbance like wildfire, drought, and subsequent tree mortality (Schofield et al. 2020, pp. 5, 8). This unit also has the largest percentage of moderate canopy cover and large tree overlap, which may explain why this unit is doing so well (see Table 9). Our habitat analysis found this unit has suitable habitat with an overall habitat suitability score of 4. Overall, the current condition of the Yosemite analysis unit is stable based on our habitat analysis (see Table 12).

Sierra Analysis Unit Condition

The Sierra analysis unit includes both the Sierra National Forest and other private lands in the area within the CSO range. The Sierra analysis unit has been part of an ongoing demography

study within the CSO range, with data ranging back to the early 1990s (Jones et al. 2018, p. entire); most of the area within this study was on public land managed by the U.S. Forest Service. This area has high apparent adult survival with male adult survival found to be 0.890 (± 0.016) and female adult survival to be 0.885 (±0.016) (Blakesley et al. 2010, p. 12). Reproductive output has varied over time (Franklin et al. 2004, p. 24; Blakesley et al. 2010, pp. 17–19). When only considering occupancy, population declines have been modeled to be -13% (95% Confidence Interval -26% to 0%) (Conner et al. 2016, p. 15). Over the same period, mark-recapture based population models showed a decline of 31% (95% CI: -50% to -4%) (Conner et al. 2016, p. 15). Natural and anthropogenic fragmentation due to low elevations, dry conditions, and accentuated logging may limit dispersal within this analysis unit (Gutiérrez et al. 2017, pp. 204–206).

The results of our habitat analysis for the Sierra analysis unit found the unit contains 9% large trees, 47% moderate canopy cover, and 6% overlap of large trees and moderate canopy cover. These results suggest the habitat has degraded from historical condition. Our fire analysis finds 44% of the Sierra analysis unit burned between 1984 and 2021, with only 7% at high-severity. Between 2011 and 2021, 7% of the unit burned at high-severity. From 1993–2021, wildfires have burned 45% of PAC acreage in the Sierra National Forest, part of this analysis unit. Including only PAC acres within fire perimeters, wildfires have burned 65% at high- or moderate-severity (Keane in litt. 2022, p. 6).

Our habitat analysis found this unit has less suitable habitat with an overall habitat suitability score of 2. Considering our habitat analysis, recent PAC information, and demographic data, the current condition of the Sierra analysis unit is declining (see Table 12).

Sequoia-Kings Canyon Analysis Unit Condition

The Sequoia-Kings Canyon analysis unit includes Sequoia and Kings Canyon National Parks as well as private lands in the area within the CSO range. This analysis unit has been part of an ongoing demography study within the CSO range, with data ranging back to the early 1990s (Jones et al. 2018, p. entire). This analysis unit has high apparent adult survival (Blakesley et al. 2010, pp. 13–14; Conner et al. 2016, p. 11). Blakesley et al. (2010, p. 12) found male adult survival in the Sequoia-Kings Canyon analysis unit to be 0.890 (± 0.016) and female adult survival to be 0.885 (±0.016). Reproductive output, measured in both number of female young fledged per territorial female and total number of young fledged per territorial female, has increased through time (Franklin et al. 2004, p. 24; Blakesley et al. 2010, pp. 17–19). When only considering occupancy, a population change of -1% (95% Confidence Interval -15% to +15%; Conner et al. 2016, p. 15) has been calculated, indicating a relatively stable population. Results from mark-recapture population models show a possible population increase of 25%, though the confidence intervals in this case were wide (95% CI: -15% to +85%) (Conner et al. 2016, p. 15). Available summaries of ongoing monitoring in this study area show that high rates of CSO territory occupancy have been maintained through 2022 (Munton and Keane 2022, p. 2). There are no known barriers which may limit dispersal in the Sequoia-Kings Canyon analysis unit.

Our habitat analysis found the Sequoia-Kings Canyon analysis unit contains 11% large trees, 49% moderate canopy cover, and an overlap value of 8%. The high percentage of large trees and moderate canopy cover within this unit suggest the habitat is not as degraded as other Sierra Nevada

population units. Further, this unit has the second largest percentage of moderate canopy cover and large tree overlap, which may explain why this unit is doing so well (see Table 9). Our fire analysis finds that 32% of the unit burned between 1984 and 2021, with just 7% of this at high-severity. Between 2011 and 2021, 6% of this unit burned at high-severity. Most of the fire occurred in 2021 with 5% at high-severity.

Our habitat analysis found this unit has suitable habitat with an overall habitat suitability score of 4. Overall, the current condition of the Sequoia-Kings Canyon analysis unit is stable based on available demographic information and our habitat analysis (see Table 12).

Sequoia Analysis Unit Condition

The Sequoia analysis unit includes both the northern and southern portions of the Sequoia National Forest as well as private lands in the area within the CSO range. No information is available to assess the current condition of survival, fecundity, or occupancy for the Sequoia analysis unit. There are no known barriers which may limit dispersal in this analysis unit.

Habitat values for this analysis unit include 7% large trees, 37% moderate canopy cover, and a large trees and moderate canopy cover overlap of 3%. All these values are relatively low compared to the other Sierra Nevada population units. Our fire analysis finds that 60% has burned between 1984 and 2021, with 16% at high-severity. Between 2011 and 2021, 10% of the unit burned at high-severity. From 1993–2021, wildfires have burned 75% of PAC acreage in the Sequoia National Forest. Considering only PAC acres within fire perimeters, wildfires have burned 68% at high- or moderate-severity (Keane in litt. 2022, p. 6).

Our habitat analysis found this unit has the lowest habitat suitability with an overall score of 1, which is at the upper limit of our scoring boundary for this habitat suitability category. Based on our habitat analysis, which is further supported by recent PAC data, the current condition of the Sequoia analysis unit is strongly declining (see Table 12).

Inyo Analysis Unit Condition

The Inyo analysis unit is a small peripheral area that includes the Inyo National Forest as well as private lands in the area within the CSO range. This analysis unit encompasses historical spotted owl detections from 1992 and earlier. However, surveys in recent years (2019–2022) have not detected CSO (Schlick and Torres pers. comm. 2022). There are currently no known PACs within the Inyo analysis unit. The southern portion of this unit with historical detections is still considered suitable habitat, yet CSO were not detected during recent surveys (Schlick and Torres pers. comm. 2022). There are no known barriers which may limit dispersal in this analysis unit.

Habitat values for this unit includes 7% large trees, 26% moderate canopy cover, and an overlap value of 3%. This unit contains low habitat values compared to other Sierra Nevada population units. The very low percentage of canopy cover for this unit suggest degraded habitat. Our fire analysis finds that 36% of this unit has burned between 1984 and 2021, with 7% of this at high-severity. Between 2011 and 2021, none of the unit burned at high severity. In one portion of the analysis unit, a large wildfire and windstorm event dramatically altered canopy cover and the habitat no longer appears suitable (Schlick and Torres pers. comm. 2022; Torres in litt. 2022).

Our habitat analysis found this unit has the lowest habitat suitability with an overall score of 1, which is at the upper limit of our scoring boundary for this habitat suitability category. Overall, the current condition of the Inyo analysis unit is strongly declining based on our habitat analysis, which is supported by the lack of CSO detections in recent years (see Table 12).

Overall Resiliency for the Sierra Nevada Population

The current condition of analysis units throughout the Sierra Nevada population varies, with three analysis units currently considered stable, five declining, and three strongly declining (see Table 12). However, all three of the strongly declining units are at the upper boundary of our scoring system. Based on these results, the overall condition of the Sierra Nevada population is declining with an average overall habitat score of 2.4. Therefore, the Sierra Nevada population currently has low resiliency (see Table 8).

Table 12: Summary of habitat scores and overall current condition of analysis units in the Sierra Nevada population. Overall current condition is based on the demographic condition (when available), or the habitat condition for analysis units without demographic information. See Table 18 for the full habitat scoring analysis for all CSO analysis units.

Analysis Unit	Overall habitat score	Analysis unit condition
Lassen	2	Declining
Plumas	2	Declining
Tahoe	4	Stable
Eldorado	2	Declining
Humboldt-Toiyabe	1	Strongly declining
Stanislaus	3	Declining
Yosemite	4	Stable
Sierra	2	Declining
Sequoia-Kings Canyon	4	Stable
Sequoia	1	Strongly declining
Inyo	1	Strongly declining

5.3.2 Coastal-Southern California Population

Habitat within the coastal-southern California CSO population is considered to be naturally fragmented, with little dispersal occurring between subpopulations due to discontinuous mountain ranges (Gutiérrez et al. 2017, pp. 93–95). This natural fragmentation has been further fragmented by development/habitat loss in the greater southern California area. Specific information about habitat and demographic conditions, when available, is incorporated below for each of our coastal-southern California analysis units. We do not mention dispersal again within text for the specific analysis units, because as mentioned in Chapter 3.2.1, available evidence does not document successful dispersal between the San Bernardino, San Gabriel, and San Jacinto Mountains, which are adjacent mountain ranges, indicating that if dispersal does occur within this population, it is very rare (LaHaye et al. 2001, p. entire, 2004, p. entire; Gutiérrez et al. 2017, pp. 242, 250).

As previously discussed, within this population, occupancy data are only available for the San Bernardino Mountains. The San Bernardino Mountains have historically contained the largest

number of CSO, suggesting that information extrapolated from this area would lead to an optimistic view for the overall population (Gutiérrez et al. 2017, p. 242). Data from Tempel et al. (2022, pp. 20–21) showed higher occupancy in the San Bernardino Mountains than the San Jacinto and San Gabriel Mountains, and the authors suggest that other parts of coastal-southern California may also have experienced greater declines than this area.

As mentioned for the Sierra Nevada population, our habitat analyses found that habitat values for large trees and canopy cover were lower in coastal-southern California than in the Sierra Nevada (see Tables 5, 9, and 13). Overlap between canopy cover and large trees was also low (see Table 13). In southern California, high canopy cover is positively associated with CSO reproductive output, but large trees appeared to be more important than high canopy cover (Tempel et al. 2022, p. 22) and are also important for occupancy. Our analysis found large tree values for coastal-southern California are low, which may indicate lower habitat suitability in these analysis units. For this population, we conducted an additional analysis identifying the percentage of small trees within the overall population that could potentially support platform or stick nests (see Table 14). We did not conduct this analysis for each analysis unit, but show the distribution of small and large trees in Figure 15. We found that 14% of the coastal-southern California analysis units contain these small trees compared to an overall value of 1% for large trees when only trees larger than 61 cm are considered. When looking at the combined total of small trees and large trees, 16% of coastal-southern California contains potential trees that could support CSO ecological needs (see Table 14).

Table 13: Habitat component (large trees and moderate canopy cover) analysis results for analysis units within the coastal-southern California population.

Analysis Unit	Large trees	Moderate Canopy cover	Moderate Canopy Cover & Large Trees Overlap
Los Padres	3%	59%	2%
Los Padres-Angeles	1%	33%	0%
San Bernardino	2%	31%	0%
Cleveland	0%	34%	0%

Table 14: Proportion of small and large trees in coastal-southern California.

>33cm and <61cm (small trees)	>33cm (small and large trees)	>61cm (large trees)
14%	16%	1%

The threats that are likely currently impacting this population include large-scale high-severity fire, tree mortality, drought, climate change, various impacts from fuels reductions and forest management, and rodenticides. Competition with barred owls is not yet considered a current threat within this population. Impacts from these threats may not be equally distributed across the population and are not equivalent to the ways that these threats impact the Sierra Nevada population. For example, what might be considered a stochastic event in the Sierra Nevada population leading to the removal of one or a few individuals from the population, could instead be considered catastrophic if it were to occur in the coastal-southern California population because of the lower number of CSO within this population. Our fire analysis shows that 60% of the CSO

range in coastal-southern California burned between 1984 and 2021, 17% at high-severity, with 6% of the total area burned in 2020 and 1% at high-severity that year. There were no fires in 2021 within this population. Typically, 4% or less of habitat within this population burned per year with 1% or less burning at high-severity, although some years burned at higher percentages (2003 at 6% with 3% high-severity and 2007 at 8% with 4% high-severity; see Appendix I). Fire severity information by analysis unit is described below for each of our coastal-southern California analysis units and is shown in Tables 15 and 16. In addition to common threats acting on all analysis units within this population, there are also common management actions taking place throughout the analysis units comprising the coastal-southern California population. For example, analysis units containing national forests include PACs around known CSO nest trees (see 4.9 Regulatory Mechanisms and Management Actions).

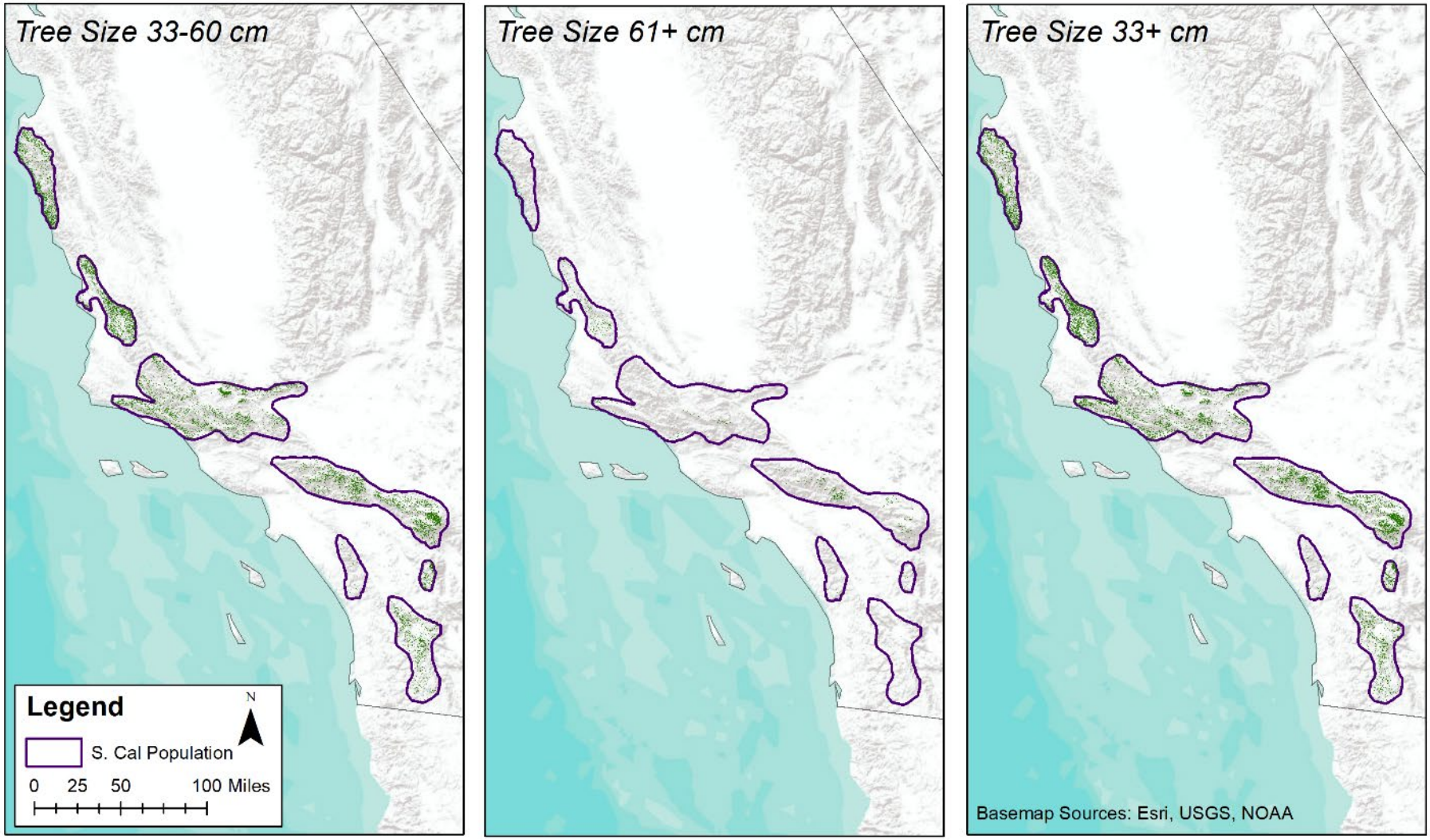


Figure 15: Tree size analysis for coastal-southern California units for large trees (61+ cm) and smaller trees (33+ cm). The first panel shows the tree sizes that are most likely to support platform nests based on data collected from platform nests on San Bernardino National Forest between 2015 and 2021 (nest type data was not available for earlier years).

Table 15: Proportion of analysis unit burned at low-, moderate-, and high-severity for the coastal-southern California population analysis units from 1984 to 2021.

Analysis Unit	Low- Severity	Moderate-Severity	High-Severity	Total
Los Padres	24.85%	24.49%	18.82%	68.16%
Los Padres-Angeles	16.94%	20.18%	17.68%	54.80%
San Bernardino	25.94%	27.61%	12.95%	66.50%
Cleveland	17.06%	16.84%	19.11%	53.01%

Table 16: Proportion of analysis unit burned at low-, moderate-, and high-severity for the coastal-southern California population analysis units from 2011 to 2021.

Analysis Unit	Low-Severity	Moderate-Severity	High-Severity	Total
Los Padres	10.36%	8.01%	5.58%	23.95%
Los Padres-Angeles	4.67%	7.58%	1.50%	13.75%
San Bernardino	10.32%	9.47%	3.20%	22.99%
Cleveland	3.02%	2.39%	0.76%	6.17%

Los Padres Analysis Unit Condition

The Los Padres analysis includes the Los Padres National Forest as well as private lands in the area within the CSO range. We do not have demographic or dispersal information about CSO in the Los Padres analysis unit.

The results of our habitat analysis for this unit found 3% large trees, 59% moderate canopy cover, and an overlap value of 2%. These percentages are higher than those in other coastal-southern California population analysis units. Our fire analysis shows between 1984 and 2021, 68% of the unit has burned with 19% at high-severity, which is relatively high compared to the other coastal-southern California analysis units. Between 2011 and 2021, 6% of this unit burned at high-severity.

Our habitat analysis found this unit has less suitable habitat with an overall habitat suitability score of 2. Overall, the current condition of the Los Padres analysis unit is declining based on our habitat analysis (see Table 17).

Los Padres-Angeles Analysis Unit Condition

The Los Padres-Angeles analysis unit includes the Angeles National Forest and a portion of the Los Padres National Forest, as well as private lands in this area. We have limited information about demographic condition from the Tempel et al. (2022, entire) long-term study (1991–2019), which is described in more detail in the San Bernardino analysis unit section. This study covered a total of 181 historical CSO territories, including ten from the eastern edge of the San Gabriel Mountains (Tempel et al. 2022, p. 4), which represents the eastern edge of the Los Padres-Angeles analysis unit. Occupancy was lower in the San Gabriel Mountains than in the San Bernardino Mountains (San Bernardino analysis unit), which included the majority of territories included in the study (Tempel et al. 2022, p. 20). In a supplemental figure showing territory occupancy, occupancy

in the San Gabriel and San Jacinto Mountains (San Bernardino analysis unit) in 2019 was about 20% (Tempel et al. 2022, Figure S1).

Habitat values for this analysis unit include 1% large trees, 33% moderate canopy cover, and 0% overlap of large trees and canopy cover. Our fire analysis shows that 55% has burned between 1984 and 2021, with 18% at high-severity. Between 2011 and 2021, 2% of the Los Padres-Angeles analysis unit burned at high severity.

Our habitat analysis found this unit has the lowest habitat suitability with an overall habitat suitability score of 1. Based on our habitat analysis and recent demographic data, the current condition of the Los Padres-Angeles analysis unit is strongly declining (see Table 17).

San Bernardino Analysis Unit Condition

The San Bernardino analysis unit includes the San Bernardino National Forest as well as private lands. Available demographic data shows a declining population over time. For the San Bernardino National Forest, discontinued studies suggested a population decline of 9% from 1987–1998 despite high apparent adult survival: 0.796 (±0.012) (LaHaye et al. 2004, pp. 1056, 1062, 1064). A 30-year dataset (1991–2019), which includes the San Bernardino analysis unit, provides information about territory occupancy and reproduction, suggesting larger declines than the earlier studies (Tempel et al. 2022, p. entire). Population impact analyses simulated these demographic rates in comparison to variables including habitat, climate, and wildfires. Specifically, within this analysis unit, the study included the San Bernardino Mountains (149 historical CSO territories) and San Jacinto Mountains (22 historical CSO territories) (Tempel et al. 2022, p. 4). Mean occupancy in the study declined by over half, from 0.82 ± 0.01 in 1991 to 0.39 ± 0.00 in 2019 (Tempel et al. 2022, pp. 16, 18), and reproductive output fluctuated throughout the study period (mean reproductive output 0.65 young/occupied territory; Tempel et al. 2022, p. 16). However, it is important to note that equivalent reproductive outputs combined with declining occupancy corresponds to overall population declines. Although the San Bernardino Mountains and San Jacinto Mountains are both part of the San Bernardino National Forest, we are not aware of information about CSO moving between these mountain ranges, highlighting limited dispersal within this analysis unit and the coastal-southern California population overall.

Habitat values for this analysis unit include 2% large trees, 31% moderate canopy cover, and 0% overlap value, suggesting that the habitat in this unit has been degraded. Our fire analysis shows that between 1984 and 2021, 66% of this unit has burned, 13% at high-severity. Between 2011 and 2021, 3% of the unit burned at high-severity. Tempel et al. (2022, p. 22) found that high-severity wildfire had an adverse effect on occupancy; when high-severity fires had burned within a CSO territory in the previous 10 years, colonization declined to almost zero and territory extinction rates increased. Overall, simulations suggested that high-severity fire was responsible for approximately 10% of the observed decline in CSO occupancy (Tempel et al. 2022, p. 22), indicating that other threats are also impacting habitat condition within this analysis unit.

Our habitat analysis found this unit has less suitable habitat with an overall habitat suitability score of 2. Considering available demographic information and our habitat analysis, the current condition of the San Bernardino analysis unit is declining (see Table 17).

Cleveland Analysis Unit Condition

The Cleveland analysis unit includes the Cleveland National Forest as well as private lands in the area within the CSO range. There is little information available to assess the current demographic condition of the Cleveland analysis unit; however, non-systematic surveys of a couple of distinct territories indicate low reproduction rates, suggesting this population may not be doing well (information retrieved from U.S. Forest Service NRIS database).

Our habitat analysis found the Cleveland analysis unit contains 0% large trees, a moderate canopy cover value of 34%, and a large trees and canopy cover overlap value of 0%. These results suggest the habitat is degraded and that the large tree habitat component is not present on the landscape. Our fire analysis supports this, with approximately 53% of the unit burned between 1984 and 2021, 19% of which was at high-severity. Between 2011 and 2021, 1% of the unit burned at high-severity.

Our habitat analysis found this unit has the lowest habitat suitability with an overall habitat suitability score of 1. Considering our habitat analysis, the current condition of the Cleveland unit is strongly declining (see Table 17).

Overall Resiliency for the Coastal-Southern California Population

The current condition of analysis units within the coastal-southern California population are two units strongly declining and two units declining (see Table 17). Based on these results, the overall condition of the coastal-southern California population is strongly declining (average overall habitat score of 1.5), and therefore, has very low resiliency (Table 8).

Table 15: Summary of habitat scores and overall current condition of analysis units within the coastal-southern California population. Overall current condition is based on the demographic condition (when available), or the habitat condition for analysis units without demographic information. See Table 18 for the full habitat scoring analysis for all analysis units.

Analysis Unit	Overall habitat score	Analysis unit condition
Los Padres	**2**	Declining
Los Padres-Angeles	**1**	Strongly declining
San Bernardino	**2**	Declining
Cleveland	**1**	Strongly declining

5.3.3. Population resiliency

As described above, the current resiliency of the Sierra Nevada population is low and the coastal-southern California population is very low. Figure 16 shows the current condition of all CSO analysis units. A summary of demographic condition and our habitat analysis for all CSO analysis units is shown in Table 18. This information was used to inform the current condition of all analysis units, and overall condition of the two CSO populations, which is how we determine population resiliency.

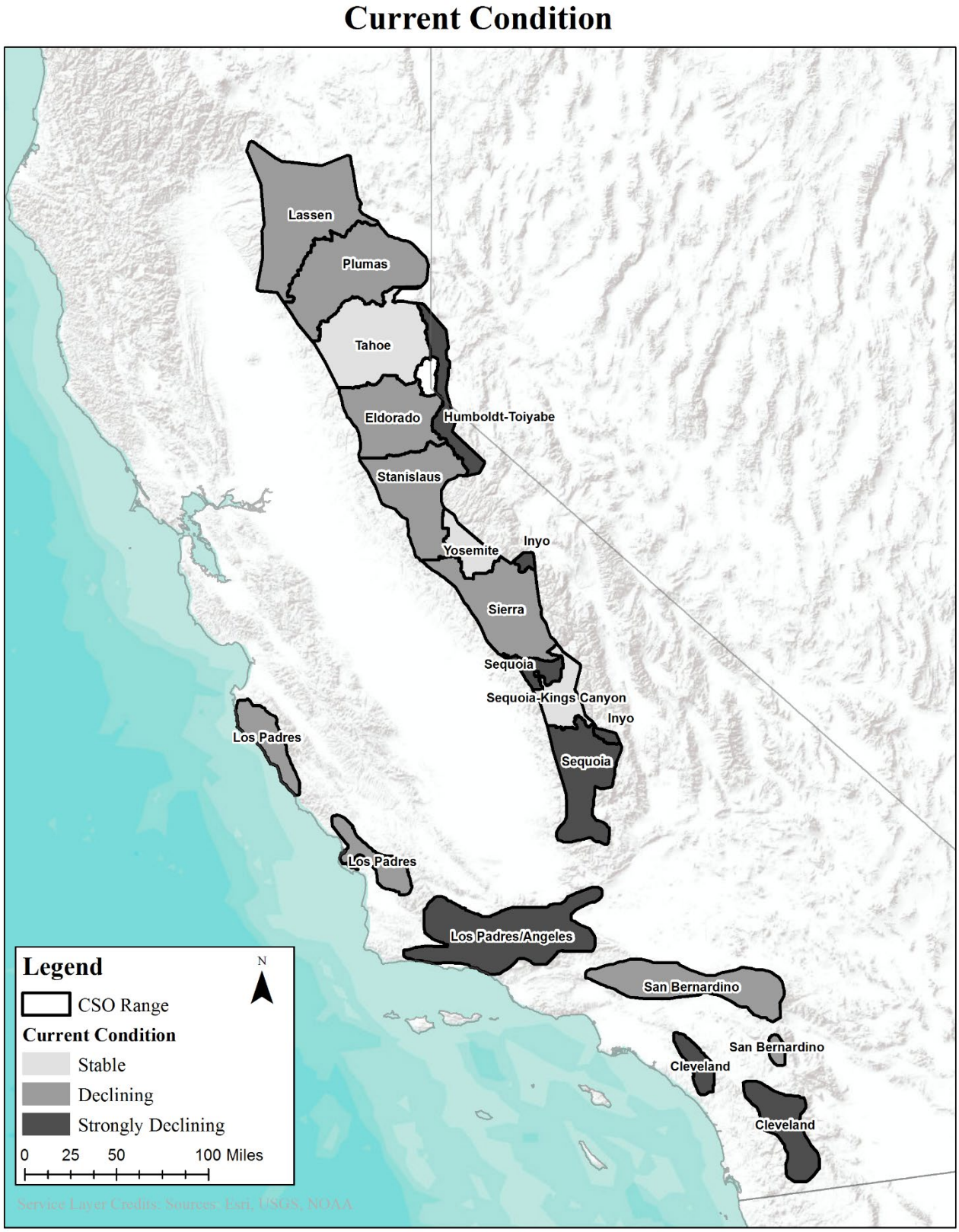


Figure 16: California spotted owl analysis units displaying the current condition

Table 16: Summary of demographic condition and our habitat analysis for all CSO analysis units. This information was used to inform the current condition for all units within the Sierra Nevada and coastal-southern California CSO populations, and population resiliency.

Analysis Unit	Large trees (LT)	LT score	Canopy cover (CC)	CC score	CC & LT	CC & LT score	Total habitat score	High severity fire	High severity score	Overall score	Habitat Suitability	Demographic condition	Overall Condition
Sierra Nevada													
Lassen	4%	1	48%	2	2%	0	3	14%	-1	2	Less suitable	declining	Declining
Plumas	5%	1	51%	2	4%	0	3	27%	-1	2	Less suitable	declining	Declining
Tahoe	7%	1	64%	3	5%	0	4	1%	0	4	Suitable	unknown	Stable
Eldorado	6%	1	57%	2	4%	0	3	12%	-1	2	Less suitable	declining	Declining
Humboldt-Toiyabe	4%	1	24%	0	2%	0	1	4%	0	1	Lowest suitability	strongly declining	Strongly declining
Stanislaus	7%	1	62%	3	5%	0	4	5%	-1	3	Less suitable	unknown	Declining
Yosemite	18%	3	36%	1	9%	1	5	5%	-1	4	Suitable	unknown	Stable
Sierra	9%	1	47%	2	6%	0	3	7%	-1	2	Less suitable	declining	Declining
Sequoia-Kings Canyon	11%	2	49%	2	8%	1	5	6%	-1	4	Suitable	stable	Stable
Sequoia	7%	1	37%	1	3%	0	2	10%	-1	1	Lowest suitability	unknown	Strongly declining
Inyo	7%	1	26%	0	3%	0	1	0%	0	1	Lowest suitability	strongly declining	Strongly declining
Coastal-Southern California													
Los Padres	3%	1	59%	2	2%	0	3	6%	-1	2	Less suitable	unknown	Declining
Los Padres-Angeles	1%	0	33%	1	0%	0	1	2%	0	1	Lowest suitability	unknown	Strongly declining
San Bernardino	2%	1	31%	1	0%	0	2	3%	0	2	Less suitable	declining	Declining
Cleveland	0%	0	34%	1	0%	0	1	1%	0	1	Lowest suitability	unknown	Strongly declining

5.4 Current Species Redundancy

To assess the current condition of redundancy, which is the species' current ability to withstand catastrophic events, this SSA Report considers the size and distribution of populations throughout the species' range, and the plausible catastrophic events to which the species may be exposed. Of the two populations throughout the species range, the Sierra Nevada population covers the most area and is the largest population, while the coastal-southern California population is small and fragmented. Catastrophic events that could impact CSO include very large high-severity wildfire, extreme drought, extreme weather events (e.g., excessive precipitation), or prolonged and persistent competition and displacement due to barred owl expansion. The difference in population structure between the Sierra Nevada and coastal-southern California population (i.e., one large relatively contiguous population compared to a fragmented population with gaps between occupied areas, respectively) could influence how CSO respond to these types of events.

California spotted owls are still distributed throughout the Sierra Nevada and this population makes up most of the spatial range of the species. This wide spread distribution throughout the Sierra Nevada offers some redundancy for the species. The coastal-southern California population is already highly fragmented and areas where demographic data are available demonstrate that declines have accelerated over the last 30 years. Further, Gutiérrez et al. (2017, p. 242) cautioned that information extrapolated from areas that historically contained the largest number of CSO would lead to an optimistic view for the overall population (Gutiérrez et al. 2017, p. 242), suggesting this population does little to contribute to redundancy for the species. A large high-severity wildfire within the San Bernardino National Forest, which historically contained the largest number of CSO in the coastal-southern California population, could have catastrophic impacts on this population, whereas a similar sized fire in the Sierra Nevada population may not have as catastrophic impacts. Overall, current CSO redundancy has declined from historical condition, making the species more vulnerable to extirpations due to a catastrophic event, especially in the coastal-southern California population.

5.5 Current Species Representation

To assess the current condition of representation, which is the species' current ability to adapt to change, this SSA Report considers the ecological setting and genetic diversity among the different populations. The California spotted owl has populations distributed across two areas: 1) the Sierra Nevada, and 2) coastal-southern California. In the Sierra Nevada, a majority of CSO occur within mid-elevation ponderosa pine, mixed-conifer, white fir, and mixed-evergreen forest types, with few CSO occurring in the lower elevation oak woodlands of the western foothills (Gutiérrez et al. 2017, p. xix). In coastal-southern California, CSO are found in riparian/hardwood forests and woodlands, live oak/big cone fir forests, and redwood/California laurel forests (Gutiérrez et al. 2017, p. xxvi). California spotted owls use stick nests more frequently in coastal-southern California compared to in the Sierra Nevada, showing diversity in nesting habitat. Historically there was evidence CSO nested in cliffs, but this has not been documented recently (Gutiérrez et al. 2020, "Breeding" section). Further, CSO in the northern portion of the range tend to have larger home range sizes than CSO in the southern portion of the range (Gutiérrez et al. 2017, p. xviii). The

climate of the Sierra Nevada is cooler and wetter compared to the more arid climate of southern California (Climate Engine 2017). Even within the Sierra Nevada, the northern portion of the range experiences more precipitation and lower mean temperatures than the southern portion of the range (Climate Engine 2017). The diversity in habitat and climate between and within the areas that we have data for suggests that the species has some flexibility to adapt to changing environmental conditions.

Of the three spotted owl subspecies (northern, California, and Mexican), CSO has the lowest genetic diversity when measured by unique haplotypes (Barrowclough et al. 1999, pp. 919, 927; Haig et al. 2004, p. 683). This suggests that CSO have lower genetic representation in general than either of the other two subspecies. However, whether the observed level of genetic diversity indicates low representation is unclear. Because the CSO has persisted throughout much of its historical range for an extended period of time, the relatively low genetic diversity may be a historical artifact rather than an indication of concern for representation. Within the CSO subspecies, genetic differences are found between CSO found in the Sierra Nevada and CSO found in southern California; this provides some degree of genetic representation, although not enough to be considered a separate subspecies (Barrowclough et al. 1999, p. 927; Gutiérrez et al. 2017, p. 101; Hanna et al. 2018, pp. 3946–3947, 3949). Whole-genome data indicates that there is greater genetic difference between CSO in the northern and southern extent of the range than between northern spotted owl and CSO in the northern portion of the range, which is consistent with isolation-by-distance (i.e., geographic differences increase with geographic scale) (Hanna et al. 2018, pp. 3946–3947). The genetic differences observed between populations, as well as the habitat and climate differences, may represent a moderate degree of adaptation and thus moderate representation. Although the species continues to inhabit different ecological settings throughout the range and shows some genetic differences within the subspecies, portions of the species range have become highly fragmented, reducing the amount of available habitat in those different ecological settings, and the overall condition of both populations have declined, which likely has resulted in reduced genetic diversity. Therefore, current CSO representation has declined from historical condition, suggesting that the ability for the taxon to adapt to change is decreased.

CHAPTER 6: FUTURE CONDITION

This chapter of the SSA Report forecasts the species' response to two plausible future scenarios. These two scenarios represent the extremes of a range of future changes in environmental conditions and success of implemented conservation efforts. The future scenarios project the influences to viability discussed in Chapter 4 into the future and consider the impacts those influences would potentially have on CSO viability. We apply the concepts of resiliency, redundancy, and representation to the future scenarios to describe the future viability of CSO. In this chapter, we describe two future scenarios and assess future resiliency for each CSO population. Scenario 1 assesses CSO future viability with an increase in the trend and magnitude of threats with implemented management efforts having mixed success. Scenario 2 assesses the viability of the species if the trend and magnitude of threats were to continue at the current trajectory into the future with implemented management efforts being fully successful. Table 19 provides a comparison of the assumptions made for each scenario. By using two scenarios representing the extremes of

plausible future projections for the species, it allows us to consider the full range of future possibilities for predicting the future viability of the species and incorporates any uncertainty regarding the impact of future environmental conditions and the success of implemented conservation efforts. For this SSA Report, the future was assessed at approximately 40–50 years. This range represents our best professional judgment of the projected future conditions related to climate change for California, CSO generation time, and regeneration time of large trees (likely only medium trees transitioning to large).

Table 17: Future scenario comparison table

Threats	Scenario 1: Increasing intensity of threats with mixed management success	Scenario 2: Current trajectory of threats with successful management efforts
Large-scale High-Severity Fire	Increase	Slight increase or stable
Tree Mortality	Increase	Stable or decrease slightly
Drought	Increase	Slight increase
Climate Change	Increase	Slight increase
Fuels Reductions and Forest Management	Increase (both positive and negative impacts)	Increase (both positive and negative impacts)
Barred Owls	Increase	Stable or decrease
Rodenticides	Increase	Remain stable
Disease and Parasites	Increase	Remain stable
Development	Increase	Remain stable
Recreation	Increase	Remain stable

6.1 Future Scenario Summary of Methods

We considered two potential future scenarios and assessed the viability of CSO under both. For each scenario (see 6.3 Scenario 1 and 6.4 Scenario 2), we include a description of the scenario assumptions, and explain expected changes in threats and how the threats would impact the species ecological needs. Current analysis unit condition and overall current population resiliency were determined as described in the current condition section of the SSA Report using demographic information and the results our habitat analysis (see 5.3 Current Analysis Unit Condition and Population Resiliency). Our future analysis uses the current condition of each analysis unit as a baseline and then incorporates future threat projections to determine whether analysis units will increase, decline, or remain stable (i.e., current condition level) into the future.

Our assumptions regarding barred owl expansion and the success of future management differ under the two scenarios. Under future scenario 1, we assume the significant threats of barred owl expansion will increase in magnitude into the future and that future management efforts, specifically barred owl removal efforts, are not successful such that barred owls have expanded throughout the entire range. To incorporate the large negative impacts barred owls would have on the demographic rates of all analysis units, we incorporated a barred owl score into our future condition analysis. In order to show how this threat will have impacts on demographic rates, we used the current condition analysis as a baseline to assign a demographic score from which to subtract the barred owl score. Baseline demographic scores for the future analysis are based on the

results of our current habitat analysis scores. Barred owl scores under scenario 1 are -1 for all analysis units to represent the large negative impacts to demographic rates that are projected to occur. Under scenario 2, all barred owl scores are 0 to represent the threat is being successfully addressed and there are no or very minimal impacts to the demographic condition of each analysis unit due to that specific threat. Barred owl scores are added to the baseline demographic score for a future demographic score.

Our assumption regarding high-severity wildfire risk differ under the two scenarios. Under scenario 1, so to incorporate an increased level of high-severity wildfire risk, we assume all units will have high-severity wildfire values of 4% or greater (as defined in 5.1 Current Condition Summary of Methods), so we adjusted the high-severity score included in the current condition analysis for all analysis units to -1. For scenario 2, we left the high-severity score the same as the current condition since we expect threats to continue at the current trajectory.

To represent future changes in habitat due to climate change and drought, we adjusted the current condition habitat analysis scores to represent the varying levels of impact to each habitat component. For scenario 1, we decreased the large tree values by 10%, the moderate canopy cover by 15%, and decreased the overlap values for all units to represent the largest likely negative impacts to habitat condition. For scenario 2, we decreased the large tree values by 5%, the moderate canopy cover by 10%, and maintained the current overlap score to represent the smallest likely negative impacts to habitat condition.

Habitat condition within each analysis unit was assessed using the scoring system in Table 6. As in the current condition analysis, for our future habitat analysis we sum all habitat scores across the analysis unit for a future habitat condition. Finally, to determine overall future habitat condition of a particular unit we average the habitat and demographic scores for that analysis unit, and then establish overall condition using the definitions in Table 7.

For population resiliency, we average scores for all analysis units within a population and then determine population resiliency using the definitions in Table 8. To assess the future condition of redundancy under both future scenarios, we consider the size and distribution of the two CSO populations throughout the species' range under the assumptions of that scenario, and the plausible catastrophic events to which the species may be exposed. To assess the future condition of representation for both scenarios, we consider the ecological setting and genetic diversity among the two populations in the future.

6.2 Future Scenario Uncertainty

As explained in 5.2 Current Condition Uncertainty, there are several ecological needs where data are not available to determine the condition for any analysis unit. Our two future scenarios represent the most plausible optimistic scenario and the most plausible pessimistic scenario in an infinite number of possible future scenarios. With many of the analysis units that do not have occupancy, survival, and fecundity data, we relied only on our current habitat analysis. However, we used the available demographic information to calibrate the categories for our habitat analysis.

There are several future climate projections that have been developed for different regions of California for California's Fourth Climate Change Assessment that take into account different scenarios of greenhouse gas emissions into the future (see 4.4 Climate Change). Although there is currently very little species-specific climate change information that exists to assess CSO and its future condition, the threats that interact synergistically with climate change (i.e., high-severity wildfire, drought, and tree mortality) are expected to grow in magnitude over time with increasing greenhouse gas emissions. The threat from wildfires is associated with the effects of climate change, such as increased drought, lower soil moisture, and decreased snowpack. Therefore, fire will continue to be a threat into the future with greater fire threat associated with increasing greenhouse emissions. We expect the pattern of increasing severity of fire and area burned in fires will continue to increase into the future under both future scenarios, with the largest increases under Scenario 1.

6.3 Scenario 1

Scenario 1 considers CSO viability if some of the significant threats were to increase in magnitude into the future and future management efforts have mixed success in addressing those threats. Under this scenario, climate change models under RCP 8.5 project temperature increases of 4.5–6°F, depending on the portion of the range. Increases in temperatures will likely increase extreme weather events including heat waves and drought conditions (Kadir et al. 2013, pp. 38, 48). With increased drought conditions, tree mortality and large-scale high-severity fire are likely to increase in frequency and size, especially if fuel loads in forests are not decreased (Westerling and Bryant 2008, pp. S244–S248; Abatzoglou and Williams 2016, pp. 11770, 11773; Young et al. 2017, p. 78). Extreme weather events or significant changes in interannual climate variability may have negative impacts on CSO survival and reproduction. Although there are some protections in place for CSO on public lands, timber harvest values can vary year to year. Therefore, it is possible that increases in timber harvest targets may reduce CSO habitat that is available now or that may be available in the future for CSO to establish new territories and disperse beyond the protected activity centers. Without continued ongoing experimental removals, barred owls will likely continue to expand their range into CSO habitat, eventually reaching a point of exponential increase and significantly displacing and outcompeting CSO on the landscape (Keane et al. 2018, pp. 8, 47). The timeline for barred owl expansion and replacement of CSO on the landscape is unknown; however, because they were able to expand so quickly within the northern spotted owl range, under future scenario 1 we assume barred owls would move beyond the Sierra Nevada and continue to expand into coastal-southern California. This expansion could be due to current experimental removal efforts becoming less successful over time (i.e., decreased experimental removal efforts) or the species being able to cross what was thought to be unsuitable habitat, like the Central Valley. Under scenario 1 it is also possible that rodenticide use could increase in California due to the legalization of marijuana in 2016. There will likely be an increase in demand of marijuana, which may increase illegal grow sites associated with the use of anticoagulant rodenticides in California if the cost of buying land and acquiring/maintaining permits to legalize a grow operation is too high (Soboroff and Koss 2017, p. entire; Yakowicz 2018, p. entire; Harrison 2018, p. entire). There is evidence that changing climate conditions could increase pathogen development and occurrence (Harvell et al. 2002, p. 2158), therefore there is a slight chance that disease and parasites may become a more significant issue in the future. Finally, development may continue to encroach upon CSO habitat as

the California human population continues to grow (California Economic Forecast 2016, pp. xii–xiii, 233–236).

6.3.1 Scenario 1 Future Analysis Unit Condition and Population Resiliency

Under future scenario 1, an increase in large-scale high-severity fire and full barred owl expansion into the CSO range will likely impact a majority of the CSO ecological needs. With an increase in large-scale high-severity fire, there may be some negative impacts to prey availability until the resources necessary to shelter and feed the prey return to the landscape (Roberts et al. 2015, pp. 107, 113; Service 2016b, pp. 60–61). However, it is only a minor impact, because although the overall abundance of prey may be reduced (Roberts et al. 2015, pp. 107, 113), some prey species are still able to persist even in areas burned at high-severity (Bond et al. 2013, pp. 114, 120; Roberts et al. 2015, pp. 107, 113). Some prey species, such as flying squirrels, may be more impacted by large-scale high-severity fire (Forsman 2018, in litt.). Large-scale high-severity fires greatly reduce multi-layered high canopy cover and large trees available on the landscape for CSO (Stephens et al. 2016, p. 1). A mosaic of fire severities in patches on the landscape can be beneficial for forest heterogeneity, but large-scale high-severity fires reduce heterogeneity that benefits CSO (Verner et al. 1992, pp. 247–248; Roberts et al. 2011, p. 610; Lee et al. 2012, p. 792; Bond et al. 2013, pp. 114, 122; Eyes et al. 2017, p. 384). With a decrease in large trees and multi-layered high canopy cover, available nest trees on the landscape will also be negatively impacted. Large-scale fires (>10,000 ha (24,711 ac)) are likely to reduce patch size at all scales for CSO within the fire area, and may even cause negative impacts to dispersal if the fire is large enough to inhibit movement. Large-scale high-severity fires likely only displace CSO from territories because they have the ability to fly and flee from a burning area, but there is evidence that fire can cause mortality to CSO (Jones et al. 2016a, p. 305), so there may be some negative impacts to survival with an increase in fires. With a reduction in some of the key habitat features due to large-scale high-severity fires, fecundity, occupancy, and population growth will likely decline under future scenario 1.

Under future scenario 1, an increase in tree mortality and drought will likely have strong impacts to canopy cover, occupancy, and population growth. Tree mortality and drought conditions significantly decreases the amount of canopy cover (Anderegg et al. 2013, pp. 30, 32); therefore, an increase of tree mortality events and drought conditions in the future will likely cause a decline in the condition of moderate canopy cover. California spotted owl occupancy sharply declines in habitat with less than 40% canopy cover (Tempel et al. 2016, pp. 747, 759); therefore, the significant decline in canopy cover from tree mortality and drought will likely negatively impact occupancy. California spotted owls can utilize large trees even if the trees are dead, and CSO are often found nesting in snags. However, CSO are less likely to nest in large trees without sufficient canopy cover. Tree mortality events and drought conditions may have slightly positive impacts on coarse woody debris and forest heterogeneity, but it will likely not improve the condition of an analysis unit. Increased drought alone may have negative impacts to survival if not enough water is available, but it is unlikely that a drought would be significant enough to have physiological impacts.

The future impacts of climate change are likely to impact a majority of CSO ecological needs. Climate change is likely to drive the increase in severity of many of the other threats discussed including large-scale high-severity fire, tree mortality, and drought. Climate change has other

potential impacts to the ecosystem, making it difficult to fully predict the specific impacts to CSO. Canopy cover and large trees will likely decline due to the multiple impacts of climate change and the potential shift in plant communities that may result (Gutiérrez et al. 2017, pp. 132, 215, 288). The significant decrease in both canopy cover and large trees will likely result in negative impacts to forest heterogeneity and available nest trees. With many of the habitat components degraded, dispersal will also likely be negatively impacted because there may be limited habitat remaining for an individual CSO to move across the landscape and establish a territory. Further, extreme weather events and heat waves associated with climate change will likely negatively impact survival. With a decline in habitat components and an increase in climate variability and extreme weather events, fecundity will likely decline. Also, climate change modeling predicts a decline in occupancy under multiple emission scenarios by 2052 (Jones et al. 2016b, p. 901). Finally, with a decrease in survival, fecundity, and occupancy, population growth will likely decline due to climate change under future scenario 1.

If the severity of interannual climate variability increases due to climate change, there may be strong negative impacts to fecundity. Significant variability of weather patterns under RCP 8.5 will likely result in a decline in fecundity. Survival may also be negatively impacted by an increase in interannual climate variability, but it is dependent on the nature of the variability and will likely be a weak impact. With a decrease in fecundity, there will likely be a decrease in population growth, but since CSO is a long-living species with generally low reproductive rates, the impacts of interannual climate variability may be reduced as long as there are occasional years with weather patterns suitable for reproduction.

Under future scenario 1, an increase in certain fuels reductions and forest management actions, like clearcutting, would have strong negative impacts on canopy cover, large trees, dispersal, fecundity, and occupancy. Clearcutting removes canopy cover, large trees, and nest trees from the landscape, which would significantly degrade habitat in the future. With a decrease in canopy cover and large trees, the habitat remaining for patch size would also decrease. In northern spotted owls, clearcutting has been shown to reduce dispersal and habitat use (Forsman et al. 1984, p. 25; Carey et al. 1990, p. 11; Miller et al. 1997, pp. 140, 145–148). The decrease in dispersal and habitat use would likely cause a decrease in fecundity, occupancy, and population growth.

Mechanical thinning would likely increase under future scenario 1, but current protections would likely remain in place within known CSO habitat. Current protections strictly limit the amount of habitat that can be thinned within known CSO territories. Mechanical thinning will likely have negative impacts on canopy cover and coarse woody debris. However, if mechanical thinning is done in a way that maintains owl habitat, the negative impacts are likely offset by the benefits of reducing fuel loads and reducing the potential of large-scale high-severity fire. For example, it is predicted that there would be little impact to CSO if multi-layered high canopy cover in a territory is reduced to 30% of the territory and the area thinned remains at moderate canopy cover (Tempel et al. 2016, p. 761). However, it is important to note that too much thinning can result in negative impacts to fecundity, occupancy, and population growth, so a balance must be maintained (Tempel et al. 2016, pp. 761–762).

An increase in salvage logging under future scenario 1 would likely result in a small decrease of prey abundance due to the loss of food and shelter. However, some prey species are able to

persist in more open habitat; therefore, some prey species will likely still be available (Bond et al. 2013, pp. 114, 120; Roberts et al. 2015, pp. 107, 113, 2017, p. 112). There would likely be little to no impacts on canopy cover because canopy cover would likely already be reduced by either fire or tree mortality for salvage logging to occur. Large trees and coarse woody debris would all likely be negatively impacted by the removal of trees resulting in degraded conditions. There would likely be no impact to survival. Fecundity, occupancy, and population growth would likely be negatively impacted with the loss of important habitat features.

Under future scenario 1, the increase of barred owls on the landscape would have a significant negative impact on CSO prey because barred owls consume the same prey species and establish 3–5 territories within the size of one CSO territory (Mazur and James 2000, "Diet and Feeding" section; Forsman 2018, in litt.). There would likely be no impacts to the quality of the species habitat components due to barred owls. However, it is important to note that barred owls inhabit the same habitat as CSO, thus the availability of many of the habitat components for CSO would likely be reduced. The amount of nest trees available for CSO would likely significantly decline due to barred owls outcompeting and using the available nest trees. Dispersal would also strongly decline because much of the available habitat would be occupied by barred owls. Barred owls outcompeting spotted owls, particularly for food, has the potential to have a significant negative impact on the survival of CSO (Forsman 2018, in litt.). Fecundity and occupancy would likely significantly decline due to barred owls displacing CSO and reducing the available habitat for spotted owls to occupy and reproduce. With decreased survival, fecundity, and occupancy, population growth would likely also decline significantly due to barred owl expansion and competition.

Under future scenario 1, rodenticides increasing on the landscape would have few impacts on the habitat, but likely detrimental effects on individuals. Rodenticides are ingested by prey species, which reduces the amount of prey available for CSO. Prey species that have ingested rodenticides and are then eaten by CSO may then result in the death of CSO. A threat that reduces survival in a population, such as rodenticides, has the potential to be highly detrimental to the species because CSO is long-lived with low reproductive rates. Rodenticides can also impact fecundity if a parent is contaminated during the breeding season, reducing the likelihood that the nest will be successful with only one parent left. An increase in rodenticides on the landscape will likely cause a decline in population growth, primarily due to a decrease in survival of CSO.

There is a small chance that under future scenario 1 disease and parasites could become a more significant threat for CSO viability. Given the limited information available, it is difficult to predict the impacts of disease/parasites; however, there would likely be some impact to survival and/or fecundity.

If development were to increase and encroach upon CSO habitat, there would likely be significant impacts to a majority of the species' ecological needs. Development would remove canopy cover, large trees, heterogeneity and coarse woody debris. There would likely be little to no impact to survival of CSO; however, fecundity, occupancy, and population growth would decline due to the loss of suitable habitat. Although development within CSO habitat is possible, it is unlikely throughout most of the range given the majority of land is federally owned.

Finally, if recreation were to increase under future scenario 1, there would likely be few impacts to CSO. Recreation activities have little to no impact on canopy cover, large trees, heterogeneity, coarse woody debris, survival, or population growth. Fecundity or occupancy may be impacted by recreation if noises or presence of people cause the individuals to leave a nest site or occupied territory. However, there is little evidence that this is a significant threat or that it could be in the future; therefore, the impacts would likely be small if any.

6.3.1.1 Sierra Nevada Population

Lassen Analysis Unit Condition

Under future scenario 1, the Lassen analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service and Park Service lands in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Lassen unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under future scenario 1, we anticipate demographic rates and habitat conditions to decline due to the increase of threats described above. The Lassen analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 20).

Plumas Analysis Unit Condition

Under future scenario 1, the Plumas analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Plumas unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2) and we anticipate demographic rates and habitat conditions to decline further due to the increase of threats described above for scenario 1. Under future scenario 1, the Plumas analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 20).

Tahoe Analysis Unit Condition

Under future scenario 1, the Tahoe analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Tahoe analysis unit is stable based on our habitat analysis (overall habitat analysis score=4), but we anticipate habitat conditions and demographic rates will decline due to the increase of threats described above. Under future scenario 1, the Tahoe analysis unit will likely be declining (overall score=2) in 40–50 years (see Table 20).

Eldorado Analysis Unit Condition

Under future scenario 1, the Eldorado analysis unit will likely be impacted by increases of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Eldorado analysis unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under scenario 1, we anticipate demographic rates and habitat conditions will decline due to the increase of threats described above. Under future scenario 1, the Eldorado analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 20).

Humboldt-Toiyabe Analysis Unit Condition

The Humboldt-Toiyabe analysis unit is a small analysis unit on the eastern edge of the CSO range. Under future scenario 1, the Humboldt-Toiyabe analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service and Nevada State Park land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Recent PAC information and our current condition habitat analysis found the Humboldt-Toiyabe unit is strongly declining (overall habitat analysis score=1). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario 1, the Humboldt-Toiyabe analysis unit will likely be extirpated (overall score=-1) in 40–50 years (see Table 20).

Stanislaus Analysis Unit Condition

Under future scenario 1, the Stanislaus analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Stanislaus unit is declining based on our habitat analysis (overall habitat analysis score=3). Under scenario 1, we anticipate the Stanislaus analysis unit will likely continue declining (overall score=2) in 40–50 years (see Table 20).

Yosemite Analysis Unit Condition

Under future scenario 1, the Yosemite analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, barred owls, and rodenticides. Clearcutting, mechanical thinning, and salvage logging will likely not be a threat because these activities do not occur on Park Service land. The current condition of the Yosemite analysis unit is stable based on our habitat analysis (overall habitat analysis score=4), but we anticipate demographic

rates and habitat conditions will decline due to the increase of threats described above. Under future scenario 1, the Yosemite analysis unit will likely be declining (overall score=2) in 40–50 years (see Table 20).

Sierra Analysis Unit Condition

Under future scenario 1, the Sierra analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service and Park Service lands in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Sierra unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above. Under future scenario 1, the Sierra analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 20).

Sequoia-Kings Canyon Analysis Unit Condition

Under future scenario 1, the Sequoia-Kings Canyon unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, barred owls, and rodenticides. Clearcutting, mechanical thinning, and salvage logging will likely not be a threat because these activities do not occur on Park Service land. Our current condition analysis found the Sequoia-Kings Canyon unit is stable based on demographic information and our habitat analysis (overall habitat analysis score=4). Under scenario 1, we anticipate demographic rates and habitat conditions will decline due to the increase of threats described above. Under future scenario 1, the Sequoia-Kings Canyon analysis unit will likely be declining (overall score=2) in 40–50 years (see Table 20).

Sequoia Analysis Unit Condition

Under future scenario 1, the Sequoia analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition habitat analysis found the Sequoia unit is strongly declining (overall habitat analysis score=1). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario 1, the Sequoia analysis unit will likely be extirpated (overall score=-1) in 40–50 years (see Table 20).

Inyo Analysis Unit Condition

The Inyo analysis unit is a small peripheral unit. Under future scenario 1, the Inyo analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, salvage logging, barred owls, and rodenticides. Although there

are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Inyo analysis unit is strongly declining based on demographic information and our habitat analysis (overall habitat analysis score=1). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario 1, the Inyo analysis unit will likely be extirpated (overall score=-1) in 40–50 years (see Table 20).

Overall Future Resiliency for the Sierra Nevada Population

Table 20 presents the future condition for each Sierra Nevada analysis unit with the assumptions described above for future Scenario 1. Under scenario 1 almost all analysis units degrade in condition, with four analysis units considered declining, four strongly declining, and three that will likely be extirpated (see Table 20). Two of the units that will likely be extirpated under scenario 1 are currently small, peripheral units. Based on these results, under scenario 1 the future overall condition of the Sierra Nevada population will be strongly declining (average overall future condition score of 0.82). Therefore, the Sierra Nevada population has very low resiliency under future scenario 1. Figure 17 is a map showing the overall future condition of all CSO analysis units under scenario 1.

Table 180: Summary of future condition scores and overall future condition for analysis units within the Sierra Nevada population under future scenario 1. See Tables 22 and 23 for the full scoring analysis for all CSO analysis units.

Analysis Unit	Overall future condition score	Future condition – scenario 1
Lassen	1	Strongly declining
Plumas	1	Strongly declining
Tahoe	2	Declining
Eldorado	1	Strongly declining
Humboldt-Toiyabe	-1	Extirpated
Stanislaus	2	Declining
Yosemite	2	Declining
Sierra	1	Strongly declining
Sequoia-Kings Canyon	2	Declining
Sequoia	-1	Extirpated
Inyo	-1	Extirpated

6.3.1.2 Coastal-Southern California Population

Los Padres Analysis Unit Condition

Under future scenario 1, the Los Padres analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, rodenticides, development, and barred owls. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of

large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Los Padres unit is declining based on our habitat analysis (overall habitat analysis score=2). Under future scenario 1, we anticipate demographic rates and habitat conditions to decline due to the increase in threats described above. The Los Padres analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 21).

Los Padres-Angeles Analysis Unit Condition

Under future scenario 1, the Los Padres-Angeles analysis unit will likely be negatively impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, rodenticides, development, and barred owls. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Los Padres-Angeles unit is strongly declining based on our habitat analysis (overall habitat analysis score=1). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario 1, the Los Padres-Angeles analysis unit will likely be extirpated (overall score=-1) in 40–50 years (see Table 21).

San Bernardino Analysis Unit Condition

Under future scenario 1, the San Bernardino analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, rodenticides, development, and barred owls. Although there are protections in place on the Forest Service and Park Service lands in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the San Bernardino analysis unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under scenario 1, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above. Under future scenario 1, the San Bernardino analysis unit will likely be strongly declining (overall score=0), with the potential of extirpation in 40–50 years (see Table 21).

Cleveland Analysis Unit Condition

Under future scenario 1, the Cleveland analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, rodenticides, development, and barred owls. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Cleveland analysis unit is strongly declining based on our habitat analysis (overall habitat analysis score=1). Under future scenario 1, we anticipate demographic factors and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario

1, the Cleveland analysis unit will likely be extirpated (overall score=-1) in 40–50 years (see Table 21).

Overall Resiliency for the Coastal-Southern California Population

Table 21 presents the future condition for each coastal-southern California population analysis unit with the assumptions described above for future Scenario 1. Under scenario 1 all coastal-southern California analysis units degrade in condition, with two analysis units considered strongly declining and two that will likely be extirpated (see Table 21). Based on these results, the overall future condition of the coastal-southern California population under scenario 1 will likely be extirpated (average overall future condition score of -0.25), and therefore, will have no resiliency. Figure 17 is a map showing the overall future condition of all CSO analysis units under scenario 1.

Table 21: Summary of future condition scores and overall future condition for analysis units within the coastal-southern California population under future scenario 1. See Tables 22 and 23 for the full scoring analysis for all CSO analysis units.

Analysis Unit	Overall future condition score	Future condition – scenario 1
Los Padres	1	Strongly declining
Los Padres-Angeles	-1	Extirpated
San Bernardino	0	Strongly declining
Cleveland	-1	Extirpated

Table 22: Summary of our future condition analysis for all CSO analysis units under scenario 1. This information was used to inform the future condition for all units within the Sierra Nevada and coastal-southern California CSO populations, and population resiliency. The full habitat analysis for scenario 1 is shown in Table 23.

Analysis Unit	Current demographic score	Barred owls score	Total demographic score	Total habitat score	Overall score	Future condition Scenario 1
Sierra Nevada						
Lassen	2	-1	1	0	1	Strongly declining
Plumas	2	-1	1	0	1	Strongly declining
Tahoe	4	-1	3	1	2	Declining
Eldorado	2	-1	1	1	1	Strongly declining
Humboldt-Toiyabe	1	-1	0	-1	-1	Extirpated
Stanislaus	3	-1	2	1	2	Declining
Yosemite	4	-1	3	0	2	Declining
Sierra	2	-1	1	0	1	Strongly declining
Sequoia-Kings Canyon	4	-1	3	0	2	Declining
Sequoia	1	-1	0	-1	-1	Extirpated
Inyo	1	-1	0	-1	-1	Extirpated
Coastal-Southern California						
Los Padres	2	-1	1	1	1	Strongly declining
Los Padres-Angeles	1	-1	0	-1	-1	Extirpated
San Bernardino	2	-1	1	-1	0	Strongly declining

Analysis Unit	Current demographic score	Barred owls score	Total demographic score	Total habitat score	Overall score	Future condition Scenario 1
Cleveland	1	-1	0	-1	-1	Extirpated

Table 23: Full habitat analysis for future scenario 1.

Analysis Unit	Large trees (LT)	LT score	Canopy cover (CC)	CC score	CC & LT	CC & LT score	Total habitat score	High severity fire	High severity score	Total Habitat score	Overall score	Habitat Suitability	Overall Condition
Sierra Nevada													
Lassen	4%	0	48%	1	2%	0	1	14%	-1	0	**1**	Lowest suitability	**Strongly declining**
Plumas	5%	0	51%	1	4%	0	1	27%	-1	0	**1**	Lowest suitability	**Strongly declining**
Tahoe	7%	0	64%	2	5%	0	2	1%	-1	1	**2**	Less suitable	**Declining**
Eldorado	6%	0	57%	2	4%	0	2	12%	-1	1	**1**	Lowest suitability	**Strongly declining**
Humboldt-Toiyabe	4%	0	24%	0	2%	0	0	4%	-1	-1	**-1**	No suitability	**Extirpated**
Stanislaus	7%	0	62%	2	5%	0	2	5%	-1	1	**2**	Less suitable	**Declining**
Yosemite	18%	1	36%	0	9%	0	1	5%	-1	0	**2**	Less suitable	**Declining**
Sierra	9%	0	47%	1	6%	0	1	7%	-1	0	**1**	Lowest suitability	**Strongly declining**
Sequoia-Kings Canyon	11%	0	49%	1	8%	0	1	6%	-1	0	**2**	Less suitable	**Declining**
Sequoia	7%	0	37%	0	3%	0	0	10%	-1	-1	**-1**	No suitability	**Extirpated**
Inyo	7%	0	26%	0	3%	0	0	0%	-1	-1	**-1**	No suitability	**Extirpated**
Coastal-Southern California													
Los Padres	3%	0	59%	2	2%	0	2	6%	-1	1	**1**	Lowest suitability	**Strongly declining**
Los Padres-Angeles	1%	0	33%	0	0%	0	0	2%	-1	-1	**-1**	No suitability	**Extirpated**
San Bernardino	2%	0	31%	0	0%	0	0	3%	-1	-1	**0**	Lowest suitability	**Strongly declining**
Cleveland	0%	0	34%	0	0%	0	0	1%	-1	-1	**-1**	No suitability	**Extirpated**

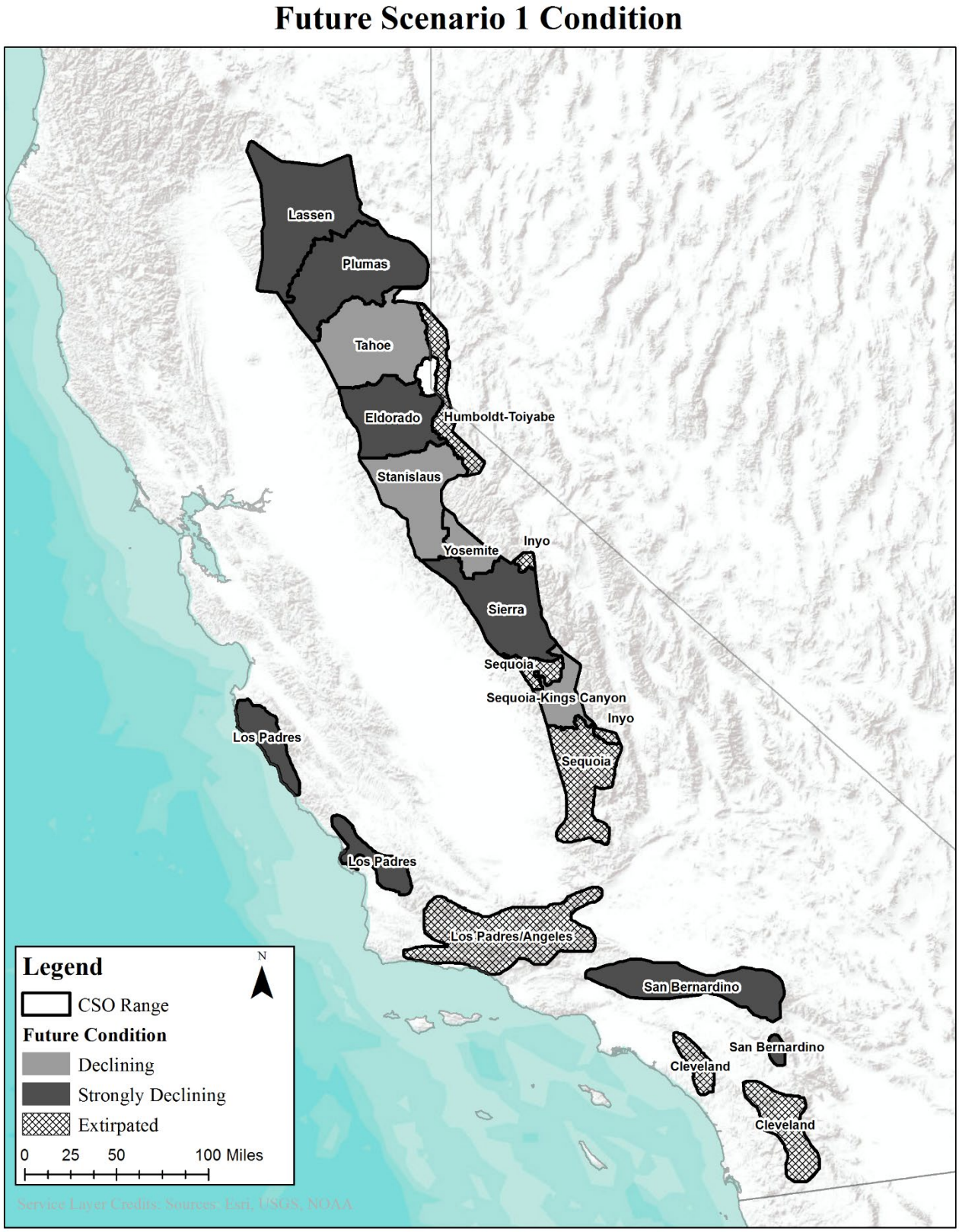


Figure 17: Map of CSO analysis units and their predicted condition under future scenario 1.

6.3.2 Future Species Redundancy

Under future scenario 1, we anticipate both populations would be less resilient compared to current condition. Because the coastal-southern California population will likely be extirpated under future scenario 1, the southern California population will contribute nothing to redundancy. The species will likely maintain a wide distribution throughout the Sierra Nevada; however, because the condition of almost all analysis units within the Sierra Nevada population are declining, the Sierra Nevada population will contribute less to redundancy under this scenario than it currently does. Therefore, under scenario 1 redundancy would decline compared to the current condition as the species would be less likely to withstand catastrophic events with only one population contributing to redundancy.

6.3.3 Future Species Representation

Predictions for future scenario 1 are that many of the habitat components identified for CSO will likely have a limited ability to withstand predicted changes and are likely to further decline in condition in the future. This would indirectly cause a decrease in representation for CSO if the diversity in habitat and climate that is currently documented declines. Further, with continued declines in occupancy, fecundity, and survival, population growth will decline and will likely further reduce genetic diversity. Under scenario 1, representation would decline compared to current condition as the species would have less flexibility to adapt to changing environmental conditions.

6.4 Scenario 2

Scenario 2 considers a future where the threats continue at the current trajectory and on-going management efforts are successful at addressing those threats. Under this scenario, climate change models under RCP 4.5 project temperature increases of 3.5–5°F, depending on the portion of the range. Under future scenario 2, drought conditions, tree mortality events, and high-severity fire will likely continue at the current trajectory. Currently, there are research actions in place to experimentally limit barred owl expansion within study areas, which have so far been successful (see 4.6 Competition and Hybridization with Barred Owls and 4.9 Regulatory Mechanisms and Management Actions) and we project will continue to be successful in limiting their expansion under this scenario. Protections would continue to stay in place for CSO on public lands, and timber harvest would remain at reduced levels on public lands. Rodenticide use would either remain the same or decrease due to continued law enforcement activity shutting down illegal marijuana grows. Under scenario 2, the current rate of human population growth will continue, leading to steadily increasing development, specifically in areas that are not on public land.

6.4.1 Scenario 2 Future Analysis Unit Condition and Population Resiliency

Under future scenario 2, large-scale high-severity fire will likely impact a majority of the CSO ecological needs. With continued large-scale high-severity fire on the landscape, there may be some negative impacts to prey availability until the resources necessary to shelter and feed the prey return to the landscape (Roberts et al. 2015, pp. 107, 113; Service 2016b, pp. 60–61). However, it is only a minor impact, because although the overall abundance of prey may be reduced (Roberts et al. 2015,

pp. 107, 113), some prey species are still able to persist even in areas burned at high-severity (Bond et al. 2013, pp. 114, 120; Roberts et al. 2015, pp. 107, 113). Large-scale high-severity fires reduce canopy cover and large trees available on the landscape for CSO (Stephens et al. 2016, p. 1). A mosaic of fire severities in patches on the landscape can be beneficial for forest heterogeneity; however, large-scale high-severity fires reduce heterogeneity that benefits CSO (Verner et al. 1992, pp. 247–248; Roberts et al. 2011, p. 610; Lee et al. 2012, p. 792; Bond et al. 2013, pp. 114, 122; Eyes et al. 2017, p. 384). With a decrease in large trees and multi-layered high canopy cover, available nest trees on the landscape will also be negatively impacted. Large-scale high-severity fires likely only displace CSO from territories because they have the ability to fly and flee from a burning area. However, there is evidence that fire can cause mortality to CSO (Jones et al. 2016a, p. 305), so there may be some negative impacts to survival with an increase in fires. With a reduction in some of the key habitat components due to large-scale high-severity fires fecundity, occupancy, and population growth will likely decline under future scenario 2.

Under future scenario 2, continued tree mortality and drought will likely have negative impacts to canopy cover, occupancy, and population growth. Tree mortality and drought conditions significantly decrease the amount of canopy cover (Anderegg et al. 2013, pp. 30, 32); therefore, continued tree mortality events and drought conditions in the future will likely reduce canopy cover. California spotted owl occupancy sharply declines in habitat with less than 40% canopy cover (Tempel et al. 2016, pp. 747, 759); therefore, the reduction in canopy cover from tree mortality and drought will likely negatively impact occupancy. Large trees, and fecundity also have the potential to be negatively impacted. California spotted owls can utilize large trees even if those trees are dead, and CSO are often found nesting in snags. However, CSO are less likely to use large trees if sufficient amount of canopy cover is not present. Tree mortality events and drought conditions may have slightly positive impacts on coarse woody debris, but those positive impacts are likely not great enough to improve the condition of individual analysis units. Drought conditions alone may have negative impacts to survival if not enough water is available, but it is unlikely that a drought would be significant enough to have physiological impacts.

The future impacts of climate change are likely to impact a majority of CSO ecological needs. Climate change is likely to drive the increase in severity of many of the other threats discussed including large-scale high-severity fire, tree mortality, and drought, even if they continue at the current trajectory. The global scale of this threat into the future will likely have other impacts that have the potential to disrupt the entire ecosystem, making it difficult to fully predict the impacts of climate change specifically to CSO. Canopy cover and large trees will likely decline due to the multiple impacts of climate change and the potential shift in plant communities that may result (Gutiérrez et al. 2017, pp. 132, 215, 288). The significant decrease in both canopy cover and large trees will likely result in negative impacts to forest heterogeneity and available nest trees. Climate change may negatively impact survival of CSO with an increase in extreme weather events and heat waves, but it will likely only be a minor impact and not affect the overall condition of any analysis unit. With a decline in habitat and an increase in climate variability and extreme weather events, fecundity will likely decline into the future. Climate change modeling predicts a decline in occupancy under even low emission scenarios by 2052 due to the impacts that climate change will likely have on habitat quality (Jones et al. 2016b, p. 901). Finally, with a decrease in survival, fecundity, and occupancy, population growth will likely decline due to climate change under future scenario 2.

If interannual climate variability changes due to projected climate change, there may be negative impacts to fecundity. Survival may also be negatively impacted by even a small increase in interannual climate variability, but it is dependent on the nature of the variability and will likely not have a significant impact. With a decrease in fecundity, there will likely be a decrease in population growth; however, since CSO is a long-lived species with generally low reproductive rates, the impacts of interannual climate variability may be minor as long as there are occasional years with weather patterns suitable for reproduction.

Under future scenario 2, continued clearcutting, primarily on private lands, would have negative impacts on canopy cover, large trees, fecundity, and occupancy. Clearcutting removes canopy cover and large trees from the landscape, which would decrease analysis unit condition in the future. In northern spotted owls, clearcutting has been shown to reduce dispersal and habitat use (Forsman et al. 1984, p. 25; Carey et al. 1990, p. 11; Miller et al. 1997, pp. 140, 145–148). The decrease in dispersal and habitat use would likely cause a decrease in fecundity, occupancy, and population growth.

Mechanical thinning would continue under future scenario 2, but current protections would likely remain in place in known CSO habitat. Current protections strictly limit the amount of habitat that can be thinned within known CSO territories. Mechanical thinning will likely have negative impacts on canopy cover and coarse woody debris. However, if mechanical thinning is done in a way that maintains CSO habitat, the negative impacts are likely offset by the benefits of reducing fuel loads and reducing the potential of large-scale high-severity fire. For example, it is predicted that there would be few impacts to CSO if multi-layered high canopy cover in a territory is reduced to 30% of the territory and if the area thinned remains at moderate canopy cover (Tempel et al. 2016, p. 761). However, it is important to note that too much thinning can result in negative impacts to fecundity, occupancy, and population growth, so a balance must be maintained (Tempel et al. 2016, pp. 761–762).

Continued salvage logging under future scenario 2 would likely result in a small decrease of prey abundance due to the loss of food and shelter. However, some prey species are able to persist in more open habitat; therefore, some prey species will likely still be available (Bond et al. 2013, pp. 114, 120; Roberts et al. 2015, pp. 107, 113, 2017, p. 112). There would likely be little to no impacts on canopy cover because canopy cover would likely already be reduced by either fire or tree mortality for salvage logging to occur. Large trees and coarse woody debris would likely be negatively impacted by the removal of trees. There would likely be no impact to survival. Fecundity, occupancy, and population growth would likely be negatively impacted with the loss of important habitat components.

Under future scenario 2, experimental removals continue to be successful in limiting the expansion of barred owls on the landscape. In areas where barred owls continue to occur in small numbers (northern Sierra Nevada population analysis units), there would likely be a small negative impact on CSO due to competition for the same prey species (Wiens et al. 2014, pp. 1–2). There would likely be no impacts to the suitability of canopy cover, large trees, or forest heterogeneity due to barred owls. Although barred owls outcompete spotted owls, particularly for food, under scenario 2 we assume that experimental removals continue to be successful and negative impacts from their temporary presence will be relatively short-lived and minor. Therefore, under scenario 2 we assume

barred owls are not having an analysis unit level impact and we do not reduce the current demographic scores to account for their impact on demographic factors.

Under future scenario 2, rodenticides would likely remain on the landscape, but they would not increase from current levels. Rodenticides have the potential to have detrimental effects to CSO, but there have been no documented cases impacting CSO; therefore, this threat is considered minor to survival, fecundity, and population growth.

Disease and parasites are also currently a minor threat to CSO. Given the limited information available, it is difficult to predict the impacts of disease/parasites. There would likely be some impacts to survival and/or fecundity. With little information available, these impacts are considered minor under future scenario 2.

If development continues and encroaches upon CSO habitat, there would likely be significant impacts to a majority of the ecological needs. California spotted owl habitat would likely decrease, as development would likely remove canopy cover and large trees. There would likely be little to no impact to survival of CSO; however, fecundity, occupancy, and population growth would significantly decline due to the loss of quality habitat.

Finally, if recreation remains at current levels under future scenario 2, there would likely be few impacts to CSO. Recreation activities have little to no impact on canopy cover, large trees, survival, or population growth. Fecundity or occupancy may be impacted by recreation if noises or presence of people cause the individuals to leave a nest site or occupied territory. However, there is little evidence that this is a significant threat or that it could be in the future; therefore, the impacts would likely be small if any.

6.4.1.1 Sierra Nevada Population

Lassen Analysis Unit Condition

Under future scenario 2, the Lassen analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. With barred owls expanding from the north, this analysis unit will likely experience the most intense influx of barred owls; however, continued experimental removals under this scenario limits any further expansion from current condition. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO ecological needs in this analysis unit, but the impacts are likely to be minor. Although there are protections in place on Forest Service and Park Service lands in this unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Lassen unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under future scenario 2, we anticipate demographic rates and habitat conditions to decline due to the increase of threats described above, especially the threat of climate change and high-severity wildfire. The Lassen analysis unit will likely be strongly declining (overall score=1) in 40–50 years under scenario 2 (see Table 24).

Plumas Analysis Unit Condition

Under future scenario 2, the Plumas analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Plumas unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under future scenario 2, we anticipate the Plumas analysis unit will likely continue declining (overall score=2)) in 40–50 years (see Table 24).

Tahoe Analysis Unit Condition

Under future scenario 2, the Tahoe analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available, even with the current protections in place. The current condition of the Tahoe analysis unit is stable based on our habitat analysis (overall habitat analysis score=4), but we anticipate habitat conditions and demographic rates will decline due to the increase of threats described above. Under future scenario 2, the Tahoe analysis unit will likely be declining (overall score=3) in 40–50 years (see Table 24).

Eldorado Analysis Unit Condition

Under future scenario 2, the Eldorado analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Eldorado analysis unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under scenario 2, we anticipate the Eldorado analysis unit will likely continue declining (overall score=2) in 40–50 years (see Table 24).

Humboldt-Toiyabe Analysis Unit Condition

Under future scenario 2, the Humboldt-Toiyabe analysis unit will likely be impacted by continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on the Forest Service and Nevada State Park land in this analysis unit to ensure

that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Recent PAC information and our current condition habitat analysis found the Humboldt-Toiyabe unit is strongly declining (overall habitat analysis score=1). Under scenario 2, we anticipate the Humboldt-Toiyabe analysis unit will likely continue strongly declining (overall score=0) with the potential of extirpation in 40–50 years (see Table 24).

Stanislaus Analysis Unit Condition

Under future scenario 2, the Stanislaus analysis unit will likely be impacted by the continued threat of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Stanislaus unit is declining based on our habitat analysis (overall habitat analysis score=3). Under scenario 2, we anticipate the Stanislaus analysis unit will likely continue declining (overall score=3) in 40–50 years (see Table 24).

Yosemite Analysis Unit Condition

Under future scenario 2, the Yosemite analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, and climate change. Clearcutting, mechanical thinning, and salvage logging will likely not be a threat because these activities do not occur on Park Service land. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. The current condition of the Yosemite analysis unit is stable based on our habitat analysis (overall habitat analysis score=4), but we anticipate demographic rates and habitat conditions will decline due to the increase of threats described above. Under future scenario 2, the Yosemite analysis unit will likely be declining (overall score=3) in 40–50 years (see Table 24).

Sierra Analysis Unit Condition

Under future scenario 2, the Sierra analysis unit will likely be impacted by increases in large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Sierra unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under future scenario 2, we anticipate the Sierra analysis unit will likely continue declining (overall score=2) in 40–50 years (see Table 24).

Sequoia-Kings Canyon Analysis Unit Condition

Under future scenario 2, the Sequoia-Kings Canyon analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, and climate change. Clearcutting, mechanical thinning, and salvage logging will likely not be a threat because these activities do not occur on Park Service land. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Our current condition analysis found the Sequoia-Kings Canyon unit is stable based on demographic information and our habitat analysis supported (overall habitat analysis score=4). Under scenario 2, we anticipate demographic rates and habitat conditions will decline due to the increase of threats described above. The Sequoia-Kings Canyon analysis unit will likely be declining (overall score=3) in 40–50 years under scenario 2 (see Table 24).

Sequoia Analysis Unit Condition

Under future scenario 2, the Sequoia analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, clearcutting, mechanical thinning, and salvage logging. Rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition habitat analysis found the Sequoia unit is strongly declining (overall habitat analysis score=1). Under scenario 2, we anticipate the Sequoia analysis unit will likely continue strongly declining (overall score=1) in 40–50 years (see Table 24).

Inyo Analysis Unit Condition

Under future scenario 2, the Inyo analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and salvage logging. Clearcutting, rodenticides, disease/parasites, development, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor. Although there are protections in place on Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Inyo unit is strongly declining based on demographic information and our habitat analysis (overall habitat analysis score=1). Under scenario 2, we anticipate the Inyo analysis unit will likely continue strongly declining (overall score =1) in 40–50 years (see Table 24).

Overall Resiliency for the Sierra Nevada Population

Table 24 presents the future condition for each Sierra Nevada analysis unit with the assumptions described above for future Scenario 2. Under scenario 2 most analysis units degrade in condition, but some maintain their current condition. Overall, under scenario 2 we project the Sierra Nevada population will have seven analysis units declining and four strongly declining (see Table 24). Based on these results, under scenario 2 the future condition of the Sierra Nevada population will be strongly declining (average overall future condition score of 1.9), but to a lesser degree than

under scenario 1. An overall future condition score of 1.9 is at the very upper limit of our scoring boundary for population condition. Therefore, the Sierra Nevada population has very low resiliency under future scenario 2, but it is closer to the boundary of low resiliency. Figure 18 is a map showing the overall future condition of all CSO analysis units under scenario 2.

Table 24: Summary of future condition scores and overall future condition for analysis units within the Sierra Nevada population under future scenario 2. See Tables 26 and 27 for the full scoring analysis for all CSO analysis units.

Analysis Unit	Overall future condition score	Future condition – scenario 2
Lassen	1	Strongly declining
Plumas	2	Declining
Tahoe	3	Declining
Eldorado	2	Declining
Humboldt-Toiyabe	0	Strongly declining
Stanislaus	3	Declining
Yosemite	3	Declining
Sierra	2	Declining
Sequoia-Kings Canyon	3	Declining
Sequoia	1	Strongly declining
Inyo	1	Strongly declining

6.4.1.2 Coastal-Southern California Population

Los Padres Analysis Unit Condition

Under future scenario 2, the Los Padres analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and development. Clearcutting, salvage logging, rodenticides, disease/parasites, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor or non-existent. Although there are protections in place on Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Los Padres unit is declining based on our habitat analysis (overall habitat analysis score=2). Under future scenario 2, we anticipate the Los Padres analysis unit will continue declining (overall score=2)in 40–50 years (see Table 25).

Los Padres-Angeles Analysis Unit Condition

Under future scenario 2, the Los Padres-Angeles analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and development. Clearcutting, salvage logging, rodenticides, disease/parasites, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor or non-existent. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the Los Padres-Angeles unit is strongly declining based

on our habitat analysis (overall habitat analysis score=1). Under scenario 2, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above. Under future scenario 2, the Los Padres-Angeles analysis unit will likely continue strongly declining (overall score=0) with the potential of extirpation in 40–50 years (see Table 25).

San Bernardino Analysis Unit Condition

Under future scenario 2, the San Bernardino analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and development. Clearcutting, salvage logging, rodenticides, disease/parasites, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor or non-existent. Although there are protections in place on Forest Service and Park Service lands in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. Our current condition analysis found the San Bernardino analysis unit is declining based on demographic information and our habitat analysis (overall habitat analysis score=2). Under scenario 2, we anticipate demographic rates and habitat conditions will continue to decline due to the increase of threats described above. Under future scenario 2, the San Bernardino analysis unit will likely be strongly declining (overall score=1) in 40–50 years (see Table 25).

Cleveland Analysis Unit Condition

Under future scenario 2, the Cleveland analysis unit will likely be impacted by the continued threats of large-scale high-severity fire, tree mortality, drought, climate change, mechanical thinning, and development. Clearcutting, rodenticides, disease/parasites, and recreation have the potential to affect CSO in this analysis unit, but the impacts are likely minor or non-existent. Although there are protections in place on the Forest Service land in this analysis unit to ensure that activity centers for CSO are protected, the threats of large-scale high-severity fire and climate change will likely reduce the amount of habitat available even with the current protections in place. The current condition of the Cleveland analysis unit is strongly declining based on our habitat analysis (overall habitat analysis score=1). Under future scenario 2, we anticipate demographic factors and habitat conditions will continue to decline due to the increase of threats described above and will no longer support the species. Under future scenario 2, the Cleveland analysis unit will likely be strongly declining (overall score=0) with the potential of extirpation in 40–50 years (see Table 25).

Overall Resiliency for the Coastal-Southern California Population

Table 25 presents the future condition for each coastal-southern California population analysis unit with the assumptions described above for future scenario 2. Under scenario 2 most coastal-southern California analysis units degrade in condition, with one analysis unit declining and three strongly declining (see Table 25). Based on these results, under scenario 2 the future condition of the coastal-southern California population will likely be strongly declining (average overall future condition score of 0.75). Therefore, the coastal-southern California population will have very low resiliency under scenario 2. Figure 18 is a map showing the overall future condition of all CSO analysis units under scenario 2.

Table 25: Summary of future condition scores and overall future condition for analysis units within the coastal-southern California population under future scenario 2. See Tables 26 and 27 for the full scoring analysis for all CSO analysis units.

Analysis Unit	Overall future condition score	Future condition – scenario 2
Los Padres	2	Declining
Los Padres-Angeles	0	Strongly declining
San Bernardino	1	Strongly declining
Cleveland	0	Strongly declining

Table 26: Summary of our future condition analysis for all CSO analysis units under future scenario 2. This information was used to inform the future condition for all units within the Sierra Nevada and coastal-southern California CSO populations, and population resiliency. The full habitat analysis for scenario 2 is shown in Table 27.

Analysis Unit	Current demographic score	Barred owls score	Total demographic score	Total habitat score	Overall score	Future condition Scenario 2
Sierra Nevada						
Lassen	2	0	2	0	1	Strongly declining
Plumas	2	0	2	1	2	Declining
Tahoe	4	0	4	2	3	Declining
Eldorado	2	0	2	1	2	Declining
Humboldt-Toiyabe	1	0	1	-1	0	Strongly declining
Stanislaus	3	0	3	2	3	Declining
Yosemite	4	0	4	2	3	Declining
Sierra	2	0	2	1	2	Declining
Sequoia-Kings Canyon	4	0	4	2	3	Declining
Sequoia	1	0	1	1	1	Strongly declining
Inyo	1	0	1	0	1	Strongly declining
Coastal-Southern California						
Los Padres	2	0	2	1	2	Declining
Los Padres-Angeles	1	0	1	-1	0	Strongly declining
San Bernardino	2	0	2	-1	1	Strongly declining
Cleveland	1	0	1	-1	0	Strongly declining

Table 27: Full habitat analysis for future scenario 2.

Analysis Unit	Large trees (LT)	LT score	Canopy cover (CC)	CC score	CC & LT	CC & LT score	Total habitat score	High severity fire	High severity score	Total Habitat score	Overall score	Habitat Suitability	Overall Condition
Sierra Nevada													
Lassen	4%	0	48%	1	2%	0	1	14%	-1	0	**1**	Lowest suitability	**Strongly declining**
Plumas	5%	0	51%	2	4%	0	2	27%	-1	1	**2**	Less suitable	**Declining**
Tahoe	7%	1	64%	2	5%	0	3	1%	-1	2	**3**	Less suitable	**Declining**
Eldorado	6%	0	57%	2	4%	0	2	12%	-1	1	**2**	Less suitable	**Declining**
Humboldt-Toiyabe	4%	0	24%	0	2%	0	0	4%	-1	-1	**0**	Lowest suitability	**Strongly declining**
Stanislaus	7%	1	62%	2	5%	0	3	5%	-1	2	**3**	Less suitable	**Declining**
Yosemite	18%	2	36%	0	9%	1	3	5%	-1	2	**3**	Less suitable	**Declining**
Sierra	9%	1	47%	1	6%	0	2	7%	-1	1	**2**	Less suitable	**Declining**
Sequoia-Kings Canyon	11%	1	49%	1	8%	1	3	6%	-1	2	**3**	Less suitable	**Declining**
Sequoia	7%	1	37%	1	3%	0	2	10%	-1	1	**1**	Lowest suitability	**Strongly declining**
Inyo	7%	1	26%	0	3%	0	1	0%	-1	0	**1**	Lowest suitability	**Strongly declining**
Coastal-Southern California													
Los Padres	3%	0	59%	2	2%	0	2	6%	-1	1	**2**	Less suitable	**Declining**
Los Padres-Angeles	1%	0	33%	0	0%	0	0	2%	-1	-1	**0**	Lowest suitability	**Strongly declining**
San Bernardino	2%	0	31%	0	0%	0	0	3%	-1	-1	**1**	Lowest suitability	**Strongly declining**
Cleveland	0%	0	34%	0	0%	0	0	1%	-1	-1	**0**	Lowest suitability	**Strongly declining**

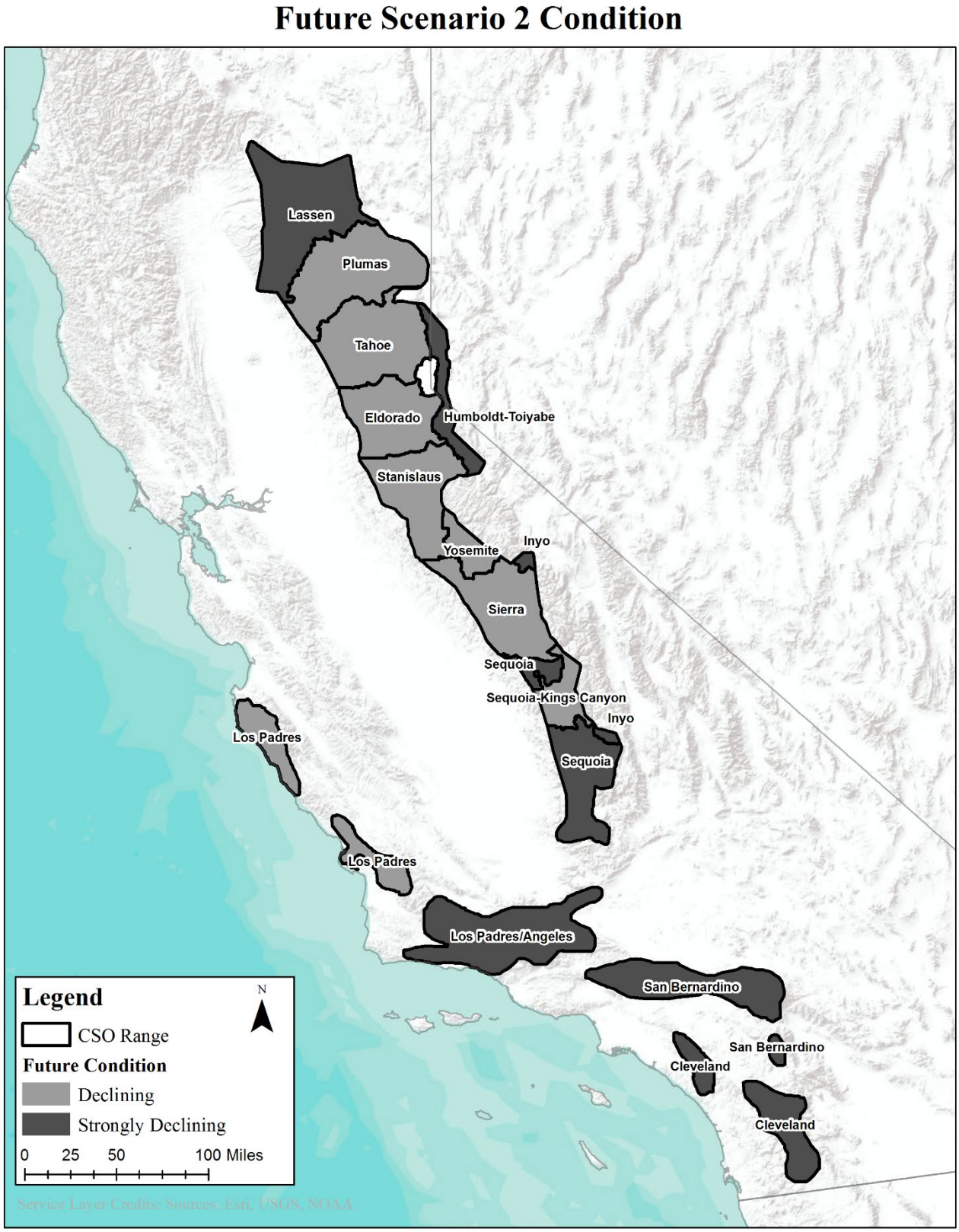


Figure 18: Map of CSO analysis units and their predicted condition under future scenario 2.

6.4.2 Future Species Redundancy

Under future scenario 2, both populations would be less resilient compared to the current condition. The species will likely maintain a majority of its current distribution throughout the Sierra Nevada, which will continue to offer some redundancy for the species. However, because the coastal-southern California population is already highly fragmented, which has accelerated over the last 30 years, the coastal-southern California population will contribute little or nothing to future redundancy for the species. Overall, the species would be less likely to withstand catastrophic events with both populations losing resiliency and a majority of analysis units declining or strongly declining with the potential to be extirpated under scenario 2. The outcome of scenario 1 and scenario 2 are very similar after 40–50 years. There are differences in how quickly the populations would decrease in condition, the likelihood of the impacts, and how many analysis units within a population may actually become extirpated. It is more likely that redundancy would be reduced, potentially from a catastrophic event, under scenario 1.

6.4.3 Future Species Representation

Under Scenario 2 many of the habitat components will likely degrade due to continued threats and the long-term impacts they cause. If the current conservation measures that are in place continue, there will be some protection for the species against certain ongoing threats; however, even with these protections in place the species is still vulnerable to large-scale high-severity fire and climate change impacts. Similar to scenario 1, under scenario 2 representation would decline compared to current condition as the species would have less flexibility to adapt to changing environmental conditions.

CHAPTER 7: OVERALL ASSESSMENT FOR SPECIES VIABILITY

The SSA Report describes the current condition as well as two plausible future scenarios that we considered important to determine the status of the species. The goal of the SSA Report is to describe the viability of the species in a manner that will address the individual, population, and species needs in terms of resiliency, redundancy, and representation. Table 28 provides a summary of the overall current condition as well as the predicted future conditions under scenario 1 and 2 for each analysis unit. Figure 19 is a side-by-side comparison map showing CSO analysis units and the current and predicted future scenario conditions.

Under the current condition, three of the 11 Sierra Nevada analysis units are in stable condition, five analysis units are declining, and three analysis units are strongly declining. In coastal-southern California, two analysis units are declining and two analysis units are strongly declining. Based on recent demographic information and our habitat analysis, we found the current resiliency of the Sierra Nevada population is low and the coastal-southern California population is very low. Overall, the species' current redundancy has declined from historical condition, reducing the species' ability to withstand a catastrophic event. Currently, the Sierra Nevada population covers the most area and has the largest population, contributing the most to species redundancy, while the coastal-southern California population is small and fragmented and contributes little to redundancy. Overall, current CSO redundancy has declined from historical condition, making the species more vulnerable

to extirpations due to a catastrophic event, especially in the coastal-southern California population where a large catastrophic event is likely to have devastating impacts to that population. Similarly, the species' current representation has also declined from historical condition, reducing the species' ability to adapt to changing conditions. The species maintains genetic differences observed between populations, as well as habitat and climate differences, which suggests some degree of adaptation; however, population declines and the lack of documented nesting in historical nesting locations suggest representation has declined.

Under future scenario 1, where the intensity of the threats increases over time and management actions are not fully effective at addressing threats, the condition of almost all analysis units would decline. Of the 15 total analysis units, no analysis units will be stable, four analysis units would likely be declining, six would likely be strongly declining, and five analysis units are likely to be extirpated. Overall, the resiliency of the Sierra Nevada would be very low under scenario 1 and because the condition of the coastal-southern California population would be extirpated, it would have no resiliency under scenario 1. Overall, redundancy and representation would decline as conditions degrade throughout the range and population resiliency declines, reducing the species' ability to withstand catastrophic events and adapt to changing environmental conditions.

Under future scenario 2, where the magnitude of the threats continues on the current trajectory and current management actions are fully effective in the future, the condition of analysis units and corresponding population resiliency decreases from current condition, although less than under future scenario 1. Of the 15 total analysis units, eight analysis units would likely be declining and seven would likely be strongly declining with the potential of extirpation. Overall, the resiliency of the Sierra Nevada would be very low under future scenario 2, although closer to the boundary of low resiliency, and the resiliency of the coastal-southern California population would be very low. Scenario 2 would likely lead to reduced redundancy and representation for the species, but to a lesser extent than scenario 1.

*Table 28: Analysis Unit Current and Future Condition Comparisons (changes from current condition in **bold**).*

Analysis Unit	Current Condition	Future Condition Scenario 1	Future Condition Scenario 2
Sierra Nevada			
Lassen	Declining	**Strongly declining**	**Strongly declining**
Plumas	Declining	**Strongly declining**	Declining
Tahoe	Stable	**Declining**	**Declining**
Eldorado	Declining	**Strongly declining**	Declining
Humboldt-Toiyabe	Strongly declining	**Extirpated**	Strongly declining
Stanislaus	Declining	Declining	Declining
Yosemite	Stable	**Declining**	**Declining**
Sierra	Declining	**Strongly declining**	Declining
Sequoia-Kings Canyon	Stable	**Declining**	**Declining**
Sequoia	Strongly declining	**Extirpated**	Strongly declining
Inyo	Strongly declining	**Extirpated**	Strongly declining

Analysis Unit	Current Condition	Future Condition Scenario 1	Future Condition Scenario 2
Coastal-Southern California			
Los Padres	Declining	**Strongly declining**	Declining
Los Padres-Angeles	Strongly declining	**Extirpated**	Strongly declining
San Bernardino	Declining	**Strongly declining**	**Strongly declining**
Cleveland	Strongly declining	**Extirpated**	Strongly declining

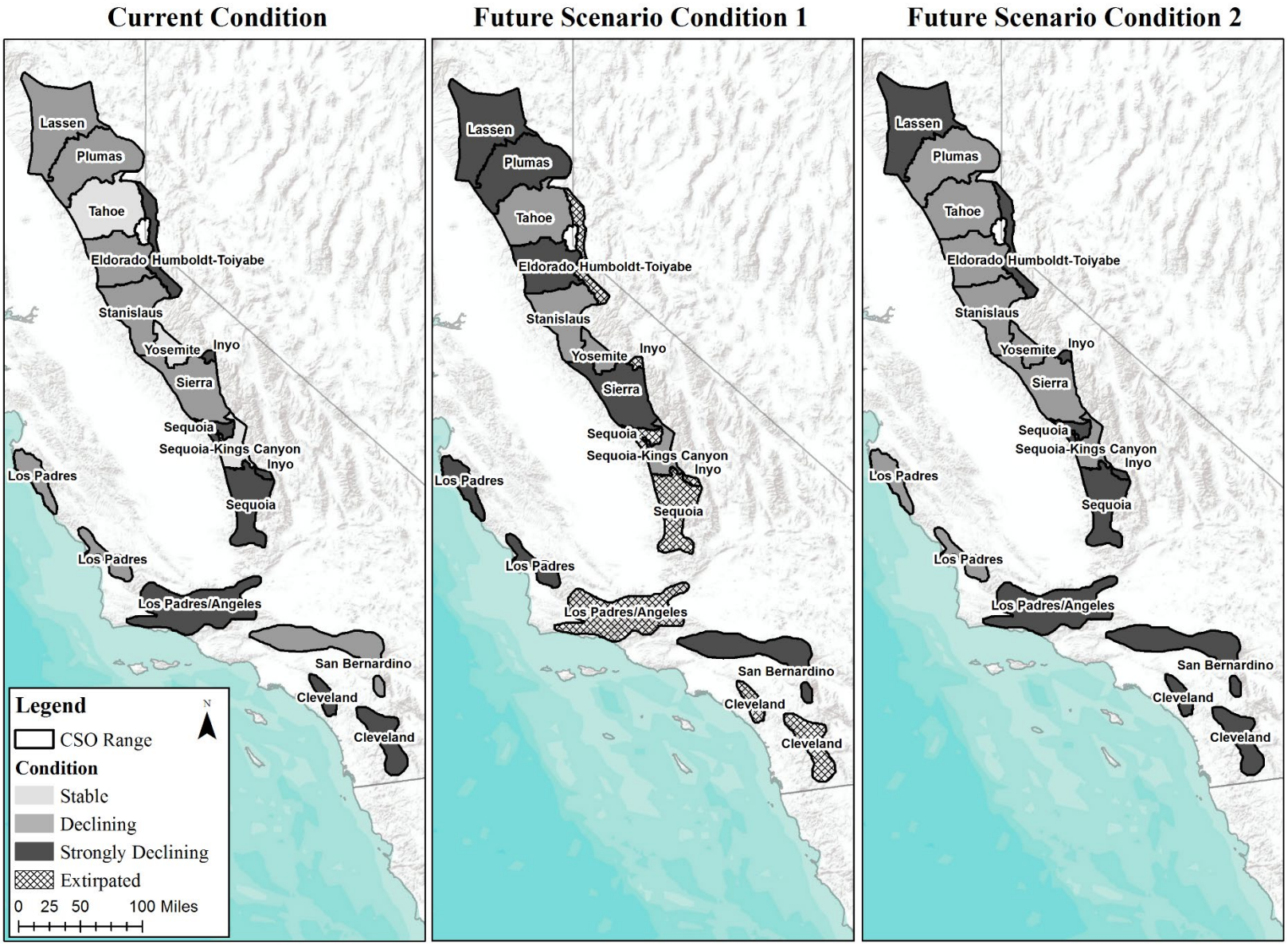


Figure 19: Maps showing the current condition of the CSO analysis units in comparison to predictions for CSO analysis units under future scenarios 1 and 2.

CHAPTER 8: LITERATURE CITED

Abatzoglou, J.T. and A.P. Williams. 2016. Impact of anthropogenic climate change on wildfire across western US forests. Proceedings of the National Academy of Sciences 113:11770–11775. https://doi.org/10.1073/pnas.1607171113

Agee, J.K. and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. Forest Ecology and Management 211:83–96. https://doi.org/10.1016/j.foreco.2005.01.034

Ager, A.A., M.A. Finney, B.K. Kerns, and H. Maffei. 2007. Modeling wildfire risk to northern spotted owl (*Strix occidentalis caurina*) habitat in Central Oregon, USA. Forest Ecology and Management 246:45–56. https://doi.org/10.1016/j.foreco.2007.03.070

Allen, C.D., A.K. Macalady, H. Chenchouni, D. Bachelet, N. McDowell, M. Vennetier, T. Kitzberger, A. Rigling, D.D. Breshears, E.H. Hogg, P. Gonzalez, R. Fensham, Z. Zhang, J. Castro, N. Demidova, J-H Lim, G. Allard, S.W. Running, A. Semerci, N. Cobb. 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. Forest Ecology and Management 259:660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Álvarez-Castañeda, S.T. and T. Lacher. 2016. Neotoma macrotis. The IUCN Red List of Threatened Species 2016: e.T14597A22370553

Anderegg, W.R.L., J.M. Kane, and L.D.L. Anderegg. 2013. Consequences of widespread tree mortality triggered by drought and temperature stress. Nature Climate Change 3:30–36. https://doi.org/10.1038/nclimate1635

[AOU] American Ornithologists' Union. 1886. The Code of Nomenclature and Check-list of North American Birds Adopted by the American Ornithologists' Union; Being the Report of the Committee of the Union on Classification and Nomenclature. American Ornithologists' Union, New York

[AOU] American Ornithologists' Union. 1957. Check-list of North American birds. 691

Arbogast, B.S., K.I. Schumacher, N.J. Kerhoulas, A.L. Bidlack, J.A. Cook, and G.J. Kenagy. 2017. Genetic data reveal a cryptic species of New World flying squirrel: Glaucomys oregonensis. Journal of Mammalogy 98:1027–1041. https://doi.org/10.1093/jmammal/gyx055

Asner, G.P., P.G. Brodrick, C.B. Anderson, N. Vaughn, D.E. Knapp, and R.E. Martin. 2015. Progressive forest canopy water loss during the 2012–2015 California drought. Proceedings of the National Academy of Sciences 113:248–255

Atuo, F.A., K. Roberts, S. Whitmore, B.P. Dotters, M.G. Raphael, S.C. Sawyer, J.J. Keane, R.J. Gutiérrez, M.Z. Peery. 2019. Resource selection by GPS-tagged California spotted owls in mixed-ownership forests. Forest Ecology and Management 433:295–304. https://doi.org/10.1016/j.foreco.2018.11.011

Barrowclough, G.F., R.J. Gutierrez, and J.G. Groth. 1999. Phylogeography of Spotted Owl (*Strix occidentalis*) populations based on mitochondrial DNA sequences: gene flow, genetic structure, and a novel biogeographic pattern. Evolution 53:919. https://doi.org/10.2307/2640731

Barrowclough, G.F., J.G. Groth, L.A. Mertz, and R.J. Gutiérrez. 2005. Genetic structure, introgression, and a narrow hybrid zone between northern and California spotted owls (*Strix occidentalis*). Molecular Ecology 14:1109–1120. https://doi.org/10.1111/j.1365-294X.2005.02465.x

Barrowclough, G.F., R.J. Gutiérrez, J.G. Groth, J.E. Lai, and D.F. Rock. 2011. The Hybrid Zone Between Northern and California Spotted Owls in the Cascade–Sierran Suture Zone. The Condor 113:581–589. https://doi.org/10.1525/cond.2011.100203

Barrows, C.W. 1981. Roost Selection by Spotted Owls: An Adaptation to Heat Stress. The Condor 83:302. https://doi.org/10.2307/1367496

Bart, J. and E.D. Forsman. 1992. Dependence of northern spotted owls (*Strix occidentalis caurina*) on old-growth forests in the western USA. Biological Conservation 62:95–100

Berigan, W.J., R.J. Gutiérrez, and D.J. Tempel. 2012. Evaluating the Efficacy of Protected Habitat Areas for the California Spotted Owl Using Long-Term Monitoring Data. Journal of Forestry 110:299–303. https://doi.org/10.5849/jof.11-018

Berigan, W.J., G.M. Jones, S.A. Whitmore, R.J. Gutiérrez, and M.Z. Peery. 2019. Cryptic wide-ranging movements lead to upwardly biased occupancy in a territorial species. Journal of Applied Ecology 56:470–480. https://doi.org/10.1111/1365-2664.13265

Bingham, B.B. and B.R. Noon. 1997. Mitigation of Habitat "Take": Application to Habitat Conservation Planning. Conservation Biology 11:127–139

Blakesley, J.A., B.R. Noon, and D.W.H. Shaw. 2001. Demography of the California Spotted Owl in Northeastern California. The Condor 103:667–677

Blakesley, J.A., B.R. Noon, and D.R. Anderson. 2005. Site occupancy, apparent survival, and reproduction of California spotted owls in relation to forest stand characteristics. Journal of Wildlife Management 69:1554–1564

Blakesley, J.A., D.R. Anderson, and B.R. Noon. 2006. Breeding dispersal in the California Spotted Owl. The Condor 108:71–81

Blakesley, J.A., M.E. Seamans, M.M. Conner, A.B. Franklin, G.C. White, R.J. Gutiérrez, J.E. Hines, J.D. Nichols, T.E. Munton, D.W.H. Shaw, J.J. Keane, G.N. Steger, and T.L. McDonald. 2010. Population Dynamics of Spotted Owls in the Sierra Nevada, California. Wildlife Monographs 174:1–36. https://doi.org/10.2193/2008-475

Blakey, R.V., R.B. Siegel, E.B. Webb, C.P. Dillingham, R.L. Bauer, M. Johnson, and D.C. Kesler. 2019. Space use, forays, and habitat selection by California Spotted Owls (*Strix occidentalis occidentalis*) during the breeding season: New insights from high resolution GPS tracking.

Forest Ecology and Management 432:912–922. https://doi.org/10.1016/j.foreco.2018.10.017

Blomdahl, E.M., C.A. Kolden, A.J.H. Meddens, and J.A. Lutz. 2019. The importance of small fire refugia in the central Sierra Nevada, California, USA. Forest Ecology and Management 432:1041–1052. https://doi.org/10.1016/j.foreco.2018.10.038

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward. 2009. Habitat Use and Selection by California Spotted Owls in a Postfire Landscape. Journal of Wildlife Management 73:1116–1124. https://doi.org/10.2193/2008-248

Bond, M.L., D.E. Lee, R.B. Siegel, and M.W. Tingley. 2013. Diet and home-range size of California spotted owls in burned forest. Western Birds 44:114–126

Bond, M.L., C. Bradley, and D.E. Lee. 2016. Foraging habitat selection by California spotted owls after fire: Spotted Owls and Fire. The Journal of Wildlife Management 80:1290–1300. https://doi.org/10.1002/jwmg.21112

Brown, R.E., J.D. Brain, and N. Wang. 1997. The Avian Respiratory System: A Unique Model for Studies of Respiratory Toxicosis and for Monitoring Air Quality. Environmental Health Perspectives 105:13

Cahill, A.J. and J.S. Walker. 2000. The effects of forest fire on the nesting success of the Red-knobbed Hornbill *Aceros cassidix*. Bird Conservation International 10:109–114. https://doi.org/10.1017/S0959270900000101

CAL FIRE and Forest Service. 2019. Survey Finds 18 Million Trees Died in California in 2018

California Department of Fish and Wildlife, Natural Diversity Database. 2018. Special Animals List. Periodic publication.

California Department of Water Resources. 2021. Drought in California. California Department of Water Resources, Sacramento, California

California Wildfire and Forest Resilience Task Force. 2022. California's Strategic Plan for Expanding the Use of Beneficial Fire. State of California

Carey, A.B., J.A. Reid, and S.P. Horton. 1990. Spotted Owl Home Range and Habitat Use in Southern Oregon Coast Ranges. The Journal of Wildlife Management 54:11. https://doi.org/10.2307/3808894

Carlson, P.C., W.S. LaHaye, and A.B. Franklin. 1998. Incestuous Behavior in Spotted Owls. The Wilson Bulletin 110:562–564

Cassola, F. 2016a. Glaucomys sabrinus. The IUCN Red List of Threatened Species 2016: e.T39553A22256914. http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T39553A22256914.en. Accessed 16 Apr 2018

Cassola, F. 2016b. Neotoma fuscipes. The IUCN Red List of Threatened Species 2016: e.T14587A22371665. athttp://dx.doi.org/10.2305/IUCN.UK.2016-2.RLTS.T14587A22371665.en. Accessed 16 Apr 2018

[CDWR] California Department of Water Resources. 2022. California Water Watch. https://cww.water.ca.gov/. Accessed 1 May 2022

Chiono, L.A., D.L. Fry, B.M. Collins, A.H. Chatfield, and S.L. Stephens. 2017. Landscape-scale fuel treatment and wildfire impacts on carbon stocks and fire hazard in California spotted owl habitat. Ecosphere 8:e01648. https://doi.org/10.1002/ecs2.1648

Clark, D.A., R.G. Anthony, and L.S. Andrews. 2012. Relationship between wildfire, salvage logging, and occupancy of nesting territories by northern spotted owls: Spotted Owl Site Occupancy Following Wildfire. The Journal of Wildlife Management 77:672–688. https://doi.org/10.1002/jwmg.523

Climate Engine. 2017. Desert Research Institute and University of Idaho. http://app.climateengine.org/. Accessed 21 Dec 2017

Conner, M.M., J.J. Keane, C.V. Gallagher, T.E. Munton, and P.A. Shaklee. 2016. Comparing estimates of population change from occupancy and mark–recapture models for a territorial species. Ecosphere 7: https://doi.org/10.1002/ecs2.1538

Crozier, M.L., M.E. Seamans, R.J. Gutiérrez, P.J. Loschl, R.B. Horn, S.G. Sovern, and E.D. Forsman. 2006. Does the Presence of Barred Owls Suppress the Calling Behavior of Spotted Owls? The Condor 108:760–769

Dark, S.J., R.J. Gutiérrez, and G.I. Gould. 1998. The Barred Owl (*Strix varia*) Invasion in California. The Auk 115:50–56. https://doi.org/10.2307/4089110

Dettinger, M., H. Alpert, J. Battles, J. Kusel, H. Saford, D. Fougeres, C. Knight, L. Miller, and S. Sawyer. 2018. Sierra Nevada Summary Report. California's Fourth Climate Change Assessment. Publication number: SUM-CCCA4-2018-004.

Diller, L., K. Hamm, D. Lamphear, and T. McDonald. 2012. Two decades of research and monitoring of the northern spotted owl on private timberlands in the redwood region: What do we know and what challenges remain? Proceedings of coast redwood forests in a changing California: A symposium for scientists and managers 399–404

Dilts, T.E. 2022. Multiscale habitat models for California spotted owl at the dry edge of its range using LIDAR. Department of Natural Resources and Environmental Science, University of Nevada Reno

[DOI] Department of the Interior and Office of the Solicitor, Office of the Solicitor. 2017. The Migratory Bird Treaty Act Does Not Prohibit Incidental Take. Memorandum (M-37050) to the Secretary, Deputy Secretary, Assistant Secretary for Land and Mineral Management, and the Assistant Secretary for Fish and Wildlife and Parks from the Principal Deputy Solicitor Exercising the Authority of the Solicitor Pursuant to Secretary's Order 3345

[DOI] Department of the Interior. 2022. Interior Department Invests Over $7.5 Million from the Bipartisan Infrastructure Law to Advance Wildfire Resilience in California. https://www.doi.gov/pressreleases/interior-department-invests-over-75-million-bipartisan-infrastructure-law-advance. Accessed 7 Dec 2022

[DOJ] U.S. Department of Justice. 2018. Federal, State, and Local Leaders and Experts Announce Results of Forest Watch, a Public Lands Marijuana Grow Eradication and Reclamation Project

Duchac, L.S., D.B. Lesmeister, K.M. Dugger, and R.J. Davis. 2021. Differential landscape use by forest owls two years after a mixed-severity wildfire. Ecosphere 12. https://doi.org/10.1002/ecs2.3770

Dugger, K.M., E.D. Forsman, A.B. Franklin, R.J. Davis, G.C. White, C.J. Schwarz, K.P. Burnham, J.D. Nichols, J.E. Hines, C.B. Yackulic, P.F. Doherty Jr., L. Bailey, D.A. Clark, S.H. Ackers, L.S. Andrews, B. Augustine, B.L. Biswell, J. Blakesley, P.C. Carlson, M.J. Clement, L.V. Diller, E.M. Glenn, A. Green, S.A. Gremel, D.R. Herter, J.M Higley, J. Hobson, R.B. Horn, K.P. Huyvaert, C. McCafferty, T. McDonald, K. McDonnell, G.S. Olson, J.A. Reid, J. Rockweit, V. Ruiz, J. Saenz, and S.G. Sovern. 2016. The effects of habitat, climate, and Barred Owls on long-term demography of Northern Spotted Owls. The Condor 118:57–116. https://doi.org/10.1650/CONDOR-15-24.1

Dwire, K.A. and J.B. Kauffman. 2003. Fire and riparian ecosystems in landscapes of the western USA. Forest Ecology and Management 178:61–74. https://doi.org/10.1016/S0378-1127(03)00053-7

Epanchin, P.N., J.A. Heath, P.C. Frederick. 2002. Effects of fires on foraging and breeding wading birds in the Everglades. The Wilson Bulletin 114:139–141. https://doi.org/10.1676/0043-5643(2002)114[0139:EOFOFA]2.0.CO;2

Erickson, R.A., R. Carmona, G. Ruiz-Campos, M.J. Iliff, and M. Billings. 2013. Annotated checklist of the birds of Baja California and Baja California Sur, second edition. North American Birds 66:582–613

Evens, J. and R. LeValley. 1982. Middle Coast Region. American Birds 36:890.

Eyes, S.A. 2014. The effects of fire severity on California spotted owl habitat use patterns. M.S. Thesis, Humboldt State University, Arcata, CA

Eyes, S.A., S.L. Roberts, and M.D. Johnson. 2017. California Spotted Owl (*Strix occidentalis occidentalis*) habitat use patterns in a burned landscape. The Condor 119:375–388. https://doi.org/10.1650/CONDOR-16-184.1

Fitzgerald, S.D., J.S. Patterson, M. Kiupel, H.A. Simmons, S.D. Grimes, C.F. Sarver, R.M. Fulton, B.A. Steficek, T.M. Cooley, J.P. Massey, and J.G. Sikarskie. 2003. Clinical and Pathologic Features of West Nile Virus Infection in Native North American Owls (Family Strigidae). Avian Diseases 47:602–610

[Forest Service] United States Forest Service. 2004. Record of Decision for the Sierra Nevada Forest Plan Amendment. 72

[Forest Service] United States Forest Service. 2005. Land Management Plan Part 1 Southern California National Forests Vision. United States Department of Agriculture, Forest Service, Pacific Southwest Region

[Forest Service] United States Forest Service. 2017. Drought and Tree Mortality in the Pacific Southwest Region: A synopsis of presentations and work group sessions from the Science and Management Symposium—Lessons Learned From Extreme Drought and Tree Mortality in the Sierra Nevada. In: How Can Past Events Inform Our Approach Forward? p 14

[Forest Service] United States Forest Service. 2019a. Land Management Plan for the Inyo National Forest. United States Department of Agriculture, Forest Service, Pacific Southwest Region, Inyo National Forest

[Forest Service] United States Forest Service. 2019b. Conservation Strategy for the California Spotted Owl in the Sierra Nevada Version 1.0. United States Department of Agriculture, Forest Service, Pacific Southwest Region

[Forest Service] United States Forest Service. 2019c. Conservation Strategy for the California Spotted Owl [Letter to Forest Supervisors, Eldorado, Inyo, Lassen, Modoc, Plumas, Sequoia, Sierra, Stanislaus, and Tahoe National Forests and the Lake Tahoe Basin Management Unit]

[Forest Service] United States Forest Service. 2019d. Pacific Southwest Region CSO Conservation Assurances Framework Update April 18, 2019

[Forest Service] United States Forest Service. 2021. 2021 Aerial Detection Survey Results: California. Prepared by Jeffrey Moore, Nicholas Stevens, and Meghan Woods, Region 5, Davis, CA

[Forest Service] United States Forest Service. 2022a. Confronting the Wildfire Crisis: Initial Landscape Investments to Protect Communities and Improve Resilience in America's Forests. U.S. Department of Agriculture, U.S. Forest Service

[Forest Service] United States Forest Service. 2022b. Land Management Plan for the Sierra National Forest, Pre-objection Version. United States Department of Agriculture, Forest Service, Pacific Southwest Region, Sierra National Forest

[Forest Service] United States Forest Service. 2022c. Land Management Plan for the Sequoia National Forest, Pre-objection Version. United States Department of Agriculture, Forest Service, Pacific Southwest Region, Sequoia National Forest

[Forest Service] United States Forest Service. 2022d. California Spotted Owl Humboldt-Toiyabe National Forest Carson and Bridgeport Ranger Districts ("Sierra Zone"). Prepared by Maureen Easton, Wildlife Biologist, Humboldt Toiyabe National Forest

Forsman, E. 1975. A preliminary investigation of the Spotted Owl in Oregon. Oregon State University

Forsman, E.D. 1980. Habitat utilization by spotted owls in the west-central Cascades of Oregon. Thesis, Oregon State University

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and biology of the Spotted Owl in Oregon. Wildlife Monograms

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner and D.E. Seaman. 2002. Natal and Breeding Dispersal of Northern Spotted Owls. Wildlife Monographs 1–35

Franklin, A.B., D.R. Anderson, R.J. Gutiérrez, and K.P. Burnham. 2000. Climate, Habitat Quality, and Fitness in Northern Spotted Owl Populations in Northwestern California. Ecological Monographs 70:539–590. https://doi.org/10.1890/0012-9615(2000)070[0539:CHQAFI]2.0.CO;2

Franklin, A.B., R.J. Gutiérrez, J.D. Nichols, M.E. Seamans, G.C. White, G.S. Zimmerman, J.E. Hines, T.E. Munton, W.S. LaHaye, J.A. Blakesley, G.N. Steger, B.R. Noon, D.W.H. Shaw, J.J. Keane, T.L. McDonald, and S. Britting. 2004. Population Dynamics of the California Spotted Owl (Strix occidentalis occidentalis): A Meta-Analysis. Ornithological Monographs 1–54. https://doi.org/10.2307/40166799

Franklin, A.B., P.C. Carlson, A. Rex, J.T. Rockweit, D. Garza, E. Culhane, S.F. Volker, R.J. Dusek, V.I. Shearn-Bochsler, M.W. Gabriel, and K.E. Horak. 2018. Grass is not always greener: rodenticide exposure of a threatened species near marijuana growing operations. BMC Res Notes 11:94. https://doi.org/10.1186/s13104-018-3206-z

Fujito, N.T., Z.R. Hanna, M. Levy-Sakin, R.C.K. Bowie, P-Y. Kwok, J.P. Dumbacher, and J.D. Wall. 2021. Genomic Variation and Recent Population Histories of Spotted (*Strix occidentalis*) and Barred (*Strix varia*) Owls. Genome Biology and Evolution 13:evab066. https://doi.org/10.1093/gbe/evab066

Funk, W.C., E.D. Forsman, T.D. Mullins, and S.M. Haig. 2008. Introgression and dispersal among spotted owl (*Strix occidentalis*) subspecies: Spotted owl subspecies and introgression. Evolutionary Applications 1:161–171. https://doi.org/10.1111/j.1752-4571.2007.00002.x

Gabbert, B. 2022. California agencies intend to ramp up prescribed burning. In: Wildfire Today. https://wildfiretoday.com/2022/04/04/california-agencies-intend-to-ramp-up-prescribed-burning/. Accessed 2 Jun 2022

Gabriel, M.W., L.W. Woods, R. Poppenga, R.A. Sweitzer, C. Thompson, S.M. Matthews, J.M. Higley, S.M. Keller, K. Purcell, R.H. Barrett, G.M. Wengert, B.N. Sacks, and D.L. Clifford. 2012. Anticoagulant Rodenticides on our Public and Community Lands: Spatial Distribution of Exposure and Poisoning of a Rare Forest Carnivore. PLoS ONE 7:e40163. https://doi.org/10.1371/journal.pone.0040163

Gabriel, M.W., G.M. Wengert, J.M. Higley, D.L. Clifford, R.H. Poppenga, L.W. Woods, S. McMillian, and S. Torres. 2017. Science with Solutions: Documentation, Reclamation and Monitoring of the Ecological Impacts of Marijuana Cultivation on Endangered Species. USFWS: Endangered Species Act (Section-6) Grant-in-Aid

Gabriel, M.W., L.V. Diller, J.P. Dumbacher, G.M. Wengert, J.M. Higley, R.H. Poppenga, and S. Mendia. 2018. Exposure to rodenticides in Northern Spotted and Barred Owls on remote forest lands in northwestern California: evidence of food web contamination. ACE 13:art2. https://doi.org/10.5751/ACE-01134-130102

Gallagher, C.V., J.J. Keane, P.A. Shaklee, H.A. Kramer, and R. Gerrard. 2018. Spotted owl foraging patterns following fuels treatments, Sierra Nevada, California. The Journal of Wildlife Management. https://doi.org/10.1002/jwmg.21586

Gancz, A.Y., I.K. Barker, R. Lindsay, A. Dibernardo, K. McKeever, and B. Hunter. 2004. West Nile Virus Outbreak in North American Owls, Ontario, 2002. Emerg Infect Dis 10:2136–2142. https://doi.org/10.3201/eid1012.040167

Ganey, J.L., W.M. Block, J.K. Dwyer, B.E. Strohmeyer, and J.S. Jennes. 1998. Dispersal Movements and Survival Rates of Juvenile Mexican Spotted Owls in Northern Arizona. The Wilson Bulletin 110:206–217

Ganguly, A.R., K. Steinhaeuser, D.J. Erickson III, M. Branstetter, E.S. Parish, N. Singha, J.B. Drake, and L. Buja. 2009. Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. Proceedings of the National Academy of Sciences 106:15555–15559. https://doi.org/10.1073/pnas.0904495106

[GBBO] Great Basin Bird Observatory. 2012. Nevada Comprehensive Bird Conservation Plan, ver. 1.0. Great Basin Bird Observatory, Reno, NV

Glenn, E.M., R.G. Anthony, and E.D. Forsman. 2010. Population trends in northern spotted owls: Associations with climate in the Pacific Northwest. Biological Conservation 143:2543–2552. https://doi.org/10.1016/j.biocon.2010.06.021

Glenn, E.M., R.G. Anthony, E.D. Forsman, and G.S. Olson. 2011. Local Weather, Regional Climate, and Annual Survival of The Northern Spotted Owl. The Condor 113:150–158. https://doi.org/10.1525/cond.2011.100118

Glick, P., B.A. Stein, and N.A. Edelson, editors. 2011. Scanning the conservation horizon: a guide to climate change vulnerability assessment. National Wildlife Federation, Washington, D.C.

Gomez, E.A., S. Hindmarch, and J.A. Smith. 2022. Conservation Letter: Raptors and Anticoagulant Rodenticides. Journal of Raptor Research. https://doi.org/10.3356/JRR-20-122

Greene, N. 1999. Thomomys bottae, Botta's pocket gopher. Animal Diversity Web, University of Michigan Museum of Zoology. https://animaldiversity.org/

Grinnell, J. 1928. California Spotted Owl - *Strix occidentalis occidentalis* (Xantus). University of California Publication in Zoology 32:242

[GTAC] Geospatial Technology and Applications Center, United States Forest Service. 2022. Rapid Assessment of Vegetation Condition after Wildfire (RAVG). https://burnseverity.cr.usgs.gov/ravg/. Accessed 1 Apr 2022

Gutiérrez, R.J. 1989. Hematozoa from the Spotted Owl. Journal of Wildlife Diseases 25:614–618. https://doi.org/10.7589/0090-3558-25.4.614

Gutiérrez, R.J. 2020. Invited Commentary: When a Conservation Conflict Comes Full Circle—The Spotted Owl Conflict is a Wicked Problem. Journal of Raptor Research 54:. https://doi.org/10.3356/0892-1016-54.4.337

Gutiérrez, R.J. and A.B. Carey. 1985. Ecology and management of the spotted owl in the Pacific Northwest. U.S. Department of Agriculture, Portland, OR

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted Owl (*Strix occidentalis*). In: Poole A, Gill F (eds) The Birds of North America No. 179: Life Histories for the 21st Century. The Philadelphia Academy of Sciences and the Ornithologists'. Union, Washington, D.C

Gutiérrez, R.J., M. Cody, S. Courtney, and A.B. Franklin. 2007. The Invasion of Barred Owls and its Potential Effect on the Spotted Owl: a Conservation Conundrum. Biol Invasions 9:181–196. https://doi.org/10.1007/s10530-006-9025-5

Gutiérrez, R.J., W.S. LaHaye, and G.S. Zimmerman. 2011. Breeding dispersal in an isolated population of Spotted Owls Strix occidentalis: evidence for improved reproductive output: Breeding dispersal of Spotted Owls. Ibis 153:592–600. https://doi.org/10.1111/j.1474-919X.2011.01140.x

Gutiérrez, R.J., P.N. Manley, and P.A Stine. 2017. The California spotted owl: current state of knowledge. U.S. Department of Agriculture, Albany, CA

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 2020. Spotted Owl (*Strix occidentalis*), version 1.0. Birds of the World. https://doi.org/10.2173/bow.spoowl.01

Hagmann, R.K., P.F. Hessburg, S.J. Prichard, N.A. Povak, P.M. Brown, P.Z. Fulé, R.E. Keane, E.E. Knapp, J.M. Lydersen, K.L. Metlen, M.J. Reilly, A.J. Sánchez Meador, S.L. Stephens, J.T. Stevens, A.H. Taylor, L.L. Yocom, M.A. Battaglia, D.J. Churchill, L.D. Daniels, D.A. Falk, P. Henson, J.D. Johnston, M.A. Krawchuk, C.R. Levine, G.W. Meigs, A.G. Merschel, M.P. North, H.D. Safford, T.W. Swetnam, and A.E.M. Waltz. 2021. Evidence for widespread changes in the structure, composition, and fire regimes of western North American forests. Ecological Applications 31:. https://doi.org/10.1002/eap.2431

Haig, S.M., T.D. Mullins, and E.D. Forsman. 2004. Subspecific relationships and genetic structure in the spotted owl. Conservation Genetics 5:683–705. https://doi.org/10.1007/s10592-004-1864-y

Hall, A., N. Berg, and K. Reich. 2018. Los Angeles Summary Report. California's Fourth Climate Change Assessment. University of California, Los Angeles

Hanna, Z.R., J.P. Dumbacher, R.C.K. Bowie, and J.D. Wall. 2018. Whole-Genome Analysis of Introgression Between the Spotted Owl and Barred Owl (*Strix occidentalis* and *Strix varia*, Respectively; Aves: Strigidae) in Western North America. G3 Genes|Genomes|Genetics 8:3945–3952. https://doi.org/10.1534/g3.118.200754

Hanski, I. and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society 42:3–16. https://doi.org/10.1111/j.1095-8312.1991.tb00548.x

Hanson, C.T., and M.P. North. 2009. Post-fire survival and flushing in three Sierra Nevada conifers with high initial crown scorch. Int J Wildland Fire 18:857. https://doi.org/10.1071/WF08129

Hanson, C.T. and T.Y. Chi. 2021. Impacts of Postfire Management Are Unjustified in Spotted Owl Habitat. Front Ecol Evol 9:596282. https://doi.org/10.3389/fevo.2021.596282

Hanson, C.T., M.L. Bond, and D.E. Lee. 2018. Effects of post-fire logging on California spotted owl occupancy. NC 24:93–105. https://doi.org/10.3897/natureconservation.24.20538

Hanson, C.T., D.E. Lee, and M.L. Bond. 2021. Disentangling Post-Fire Logging and High-Severity Fire Effects for Spotted Owls. Birds 2:147–157. https://doi.org/10.3390/birds2020011

Harrison, M. 2018. California's high taxes and regulation mean black market for marijuana is still appealing. The Orange County Register

Harvell, C.D., C.E. Mitchell, J.R. Ward, S. Altizer, A.P. Dobson, R.S. Ostfeld, and M.D. Samuel. 2002. Climate Warming and Disease Risks for Terrestrial and Marine Biota. Science 296:2158–2162. https://doi.org/10.1126/science.1063699

Hayward, L.S., A.E. Bowles, J.C. Ha, and S.K. Wasser. 2011. Impacts of acute and long-term vehicle exposure on physiology and reproductive success of the northern spotted owl. Ecosphere 2:1–20

Hessburg, P.F., S.J. Prichard, R.K. Hagmann, N.A. Povak, and F.K. Lake. 2021. Wildfire and climate change adaptation of western North American forests: a case for intentional management. Ecological Applications 31:1–17. https://doi.org/10.1002/eap.2432

Hobart, B.K., K.N. Roberts, B.P. Dotters, W.J. Berigan, S.A. Whitmore, M.G. Raphael, J.J. Keane, R.J. Gutiérrez, and M.Z. Peery. 2019. Site occupancy and reproductive dynamics of California spotted owls in a mixed-ownership landscape. Forest Ecology and Management 437:188–200. https://doi.org/10.1016/j.foreco.2019.01.028

Hobart, B.K., H.A. Kramer, G.M. Jones, B.P. Dotters, S.A. Whitmore, J.J. Keane, and M.Z. Peery. 2021. Stable isotopes reveal unexpected relationships between fire history and the diet of Spotted Owls. Ibis 163:253–259. https://doi.org/10.1111/ibi.12832

Hofstadter, D.F., N.F. Kryshak, M.W. Gabriel, C.M. Wood, G.M. Wengert, B.P. Dotters, K.N. Roberts, E.D. Fountain, K.G. Kelly, J.J. Keane, S.A. Whitmore, W.J. Berigan, and M.Z. Peery. 2021. High rates of anticoagulant rodenticide exposure in California Barred

Owls are associated with the wildland–urban interface. Ornithological Applications 123:duab036. https://doi.org/10.1093/ornithapp/duab036

Hofstadter, D.F., N.F. Kryshak, C.M. Wood, B.P. Dotters, K.N. Roberts, K.G. Kelly, J.J. Keane, S.C. Sawyer, P.A. Shaklee, H.A. Kramer, R.J. Gutiérrez, and M.Z. Peery. 2022. Arresting the spread of invasive species in continental systems. Frontiers in Ecol & Environ 1–7. https://doi.org/10.1002/fee.2458

Hollenbeck, J.P., S.M. Haig, E.D. Forsman, and J.D. Wiens. 2018. Geographic variation in natal dispersal of Northern Spotted Owls over 28 years. The Condor 120:530–542. https://doi.org/10.1650/CONDOR-17-164.1

Holm, S.R., B.R. Noon, J.D. Wiens, and W.J. Ripple. 2016. Potential trophic cascades triggered by the barred owl range expansion: Barred Owl Trophic Cascade. Wildl Soc Bull 40:615–624. https://doi.org/10.1002/wsb.714

Howell, S.N.G., R.A. Erickson, R.A. Hamilton, and M.A. Patten. 2001. An annotated checklist of the birds of Baja California and Baja California Sur. Monographs in Field Ornithology 3:171–203

Hull, J.M., J.J. Keane, L. Tell, and H.B. Ernest. 2010. West Nile Virus Antibody Surveillance in Three Sierra Nevada Raptors of Conservation Concern. Condor 112:168–172. https://doi.org/10.1525/cond.2010.090110

Hunsaker, C.T., B.B Boroski, and G.N. Steger. 2002. Relations between canopy cover and the occurrence and productivity of California spotted owls. In: Predicting species occurrences: issues of accuracy and scale. Island Press, Covolo, CA, pp 687–700

Hunter, J.E., R.J. Gutiérrez, and A.B. Franklin. 1994. Ectoparasites of the Spotted Owl. Journal of Raptor Research 28:232–235

Innes, R.J., D.H.V. Vuren, D.A Kelt, M.L. Johnson, J.A. Wilson, and P.A. Stine. 2007. Habitat Associations of Dusky-footed Woodrats (Neotoma fuscipes) in Mixed-conifer Forest of the Northern Sierra Nevada. Journal of Mammalogy 88:1523–1531. https://doi.org/10.1644/07-MAMM-A-002R.1

[IPCC] The Intergovernmental Panel on Climate Change. 2013a. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, . Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[IPCC] The Intergovernmental Panel on Climate Change. 2013b. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change., . Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

[IPCC] The Intergovernmental Panel on Climate Change. 2014. Climate Change 2014 Synthesis Report Summary for Policymakers. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, . Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.). Geneva, Switzerland

Irwin, L.L., L.A. Clark, D.C. Rock, and S.L. Rock. 2007. Modeling Foraging Habitat of California Spotted Owls. The Journal of Wildlife Management 71:1183–1191

Ishak, H.D., J.P. Dumbacher, N.L. Anderson, J.J. Keane, G. Valkiūnas, S.M. Haig, L.A. Tell, and R.N.M. Sehgal. 2008. Blood Parasites in Owls with Conservation Implications for the Spotted Owl (Strix occidentalis). PLoS ONE 3:e2304. https://doi.org/10.1371/journal.pone.0002304

Jennings, S., R.L. Cormier, T. Gardali, D. Press, and W.W. Merkle. 2011. Status and distribution of the Barred Owl in Marin County, California. Western Birds 42:103–110

John Muir Project of Earth Island Institute and The Wild Nature Institute. 2014. Petition to list the California Spotted Owl (*Strix occidentalis occidentalis*) as Threatened or Endangered under the Federal Endangered Species Act.

Jones, G.M., and M.Z. Peery. 2019. Phantom interactions: Use odds ratios or risk misinterpreting occupancy models. The Condor 121:duy007. https://doi.org/10.1093/condor/duy007

Jones, G.M., and M.W. Tingley. 2021. Pyrodiversity and biodiversity: A history, synthesis, and outlook. Diversity and Distributions 28:1–18. https://doi.org/10.1111/ddi.13280

Jones, G.M., R.J. Gutiérrez, D.J. Tempel, S.A. Whitmore, W.J. Berigan, and M.Z. Peery. 2016a. Megafires: an emerging threat to old-forest species. Frontiers in Ecology and the Environment 14:300–306. https://doi.org/10.1002/fee.1298

Jones G.M., R.J. Gutiérrez, D.J. Tempel, B. Zuckerberg, and M.Z. Peery. 2016b. Using dynamic occupancy models to inform climate change adaptation strategies for California spotted owls. Journal of Applied Ecology 53:895–905. https://doi.org/10.1111/1365-2664.12600

Jones, G.M., J.J. Keane, R.J. Gutiérrez, and M.Z. Peery. 2018. Declining old-forest species as a legacy of large trees lost. Divers Distrib 24:341–351. https://doi.org/10.1111/ddi.12682

Jones, G.M., R.J. Gutierrez, D.J. Tempel, W.J. Berigan, S.A. Whitmore, and M.Z. Peery. 2019. Megafire effects on spotted owls: elucidation of a growing threat and a response to Hanson et al. (2018). Nature Conservation 33:21–41. https://doi.org/10.3897/natureconservation.33.32741

Jones, G.M., R.J. Gutiérrez, W.M. Block, P.C. Carlson, E.J. Comfort, S.A. Cushman, R.J. Davis, S.A. Eyes, A.B. Franklin, J.L. Ganey, S. Hedwall, J.J. Keane, R. Kelsey, D.B. Lesmeister, M.P. North, S.L. Roberts, J.T. Rockweit, J.S. Sanderlin, S.C. Sawyer, B. Solvesky, D.J. Tempel, H.Y. Wan, A.L. Westerling, G.C. White, and M.Z. Peery. 2020a. Spotted owls and forest fire: Comment. Ecosphere 11:1–16. https://doi.org/10.1002/ecs2.3312

Jones, G.M., H.A. Kramer, S.A. Whitmore, W.J. Berigan, D.J. Tempel, C.M. Wood, B.K. Hobart, T. Erker, F.A. Atuo, N.F. Pietrunti, R. Kelsey, R.J. Gutiérrez, and M.Z. Peery. 2020b. Habitat selection by spotted owls after a megafire reflects their adaptation to historical frequent-fire regimes. Landscape Ecology 35:1199–1213. https://doi.org/10.1007/s10980-020-01010-y

Jones, G.M., A.R. Keyser, A.L. Westerling, W.J. Baldwin, J.J. Keane, S.C. Sawyer, J.D.J. Clare, R.J. Gutiérrez, and M.Z. Peery. 2021a. Forest restoration limits megafires and supports species conservation under climate change. Frontiers in Ecology and the Environment fee.2450. https://doi.org/10.1002/fee.2450

Jones, G.M., H.A. Kramer, W.J. Berigan, S.A. Whitmore, R. J. Gutiérrez, and M.Z. Peery. 2021b. Megafire causes persistent loss of an old-forest species. Animal Conservation 24:925–936. https://doi.org/10.1111/acv.12697

Kadir, T., L. Mazur, C. Milanes, and K. Randles. 2013. Indicators of climate change in California. 258

Kalansky, J., D. Cayan, K. Barba, L. Walsh, K. Brouwer, and D. Boudreau. 2018. San Diego Summary Report. California's Fourth Climate Change Assessment. University of California, San Diego. Publication number: SUM-CCCA4-2018-009.

Keane, J.J., R.A., Gerrard, C.V. Gallagher, P.A. Shaklee, T.E. Munton, and J.M. Hull. 2018. Range Expansion of the Barred Owl in the Sierra Nevada, California. PowerPoint Presentation for The Wildlife Society-Western Section Conference. Santa Rosa, CA

Kelt, D.A., D.H. Van Vuren, M.L. Johnson, J.A. Wilson, R.J. Innes, B.R. Jesmer, K.P. Ingram, J.R. Smith, S.W. Bigelow, R.D. Burnett, and P.A. Stine. 2013. Small mammals exhibit limited spatiotemporal structure in Sierra Nevada forests. J Mammal 94:1197–1213. https://doi.org/10.1644/12-MAMM-A-303

Komar, N. 2003. West Nile virus: epidemiology and ecology in North America. Advances in Virus Research 61:185–234

Kramer, A., G.M. Jones, S.A. Whitmore, J.J. Keane, F.A. Atuoa, B.P. Dotters, S.C. Sawyer, S.L. Stock, R.J. Gutiérrez, and M.Z. Peery. 2021a. California spotted owl habitat selection in a fire-managed landscape suggests conservation benefit of restoring historical fire regimes. Forest Ecology and Management 479:1-12. khttps://doi.org/10.1016/j.foreco.2020.118576

Kramer, H.A., G.M. Jones, V.R. Kane, B. Bartl-Geller, J.T. Kane, S.A. Whitmore, W.J. Berigan, B.P. Dotters, K.N. Roberts, S.C. Sawyer, J.J. Keane, M.P. North, R.J. Gutiérrez, and M.Z. Peery. 2021b. Elevational gradients strongly mediate habitat selection patterns in a nocturnal predator. Ecosphere 12:1-22. https://doi.org/10.1002/ecs2.3500

Kroll, A.J., T.L. Fleming, and L.L. Irwin. 2010. Site Occupancy Dynamics of Northern Spotted Owls in the Eastern Cascades, Washington, USA, 1990-2003. The Journal of Wildlife Management 74:1264–1274

Kryshak, N.F., E.D. Fountain, D.F. Hofstadter, B.P. Dotters, K.N. Roberts, C.M. Wood, K.G. Kelly, I.F. Papraniku, P.J. Kulzer, A.K. Wray, H.A. Kramer, J.P. Dumbacher, J.J. Keane,

P.A. Shaklee, R.J. Gutiérrez, and M.Z. Peery. 2022. DNA metabarcoding reveals the threat of rapidly expanding barred owl populations to native wildlife in western North America. bioRxiv preprint version posted April 20, 2022 30. https://www.biorxiv.org/content/10.1101/2022.04.19.488820v1

Lacher, T., R. Timm, and S.T. Álvarez-Castañeda. 2016. Thomomys bottae. The IUCN Red List of Threatened Species 2016: e.T21799A115163311

LaHaye, W.S., and R.J. Gutiérrez. 2005. The spotted owl in southern California: ecology and special concerns for the maintenance of a forest-dwelling species in a human-dominated desert landscape. Planning for biodiversity: bringing research and management together. General Technical Report PSW-GTR-195 199–209

LaHaye, W.S., R.J. Gutiérrez, and H.R. Akcakaya. 1994. Spotted Owl Metapopulation Dynamics in Southern California. The Journal of Animal Ecology 63:775. https://doi.org/10.2307/5255

LaHaye, W.S., R.J. Gutiérrez, and D.R. Call. 1997. Nest-Site Selection and Reproductive Success of California Spotted Owls. The Wilson Bulletin 109:42–51

LaHaye, W.S., R.J. Gutiérrez, and J.R. Dunk. 2001. Natal Dispersal of the Spotted Owl in Southern California: Dispersal Profile of an Insular Population. The Condor 103:691–700

LaHaye, W.S., G.S. Zimmerman, and R.J. Gutiérrez. 2004. Temporal Variation in the Vital Rates of an Insular Population of Spotted Owls (Strix occidentalis occidentalis): Contrasting Effects of Weather. The Auk 121:1056–1069

Langridge, R. 2018. Central Coast Summary Report. California's Fourth Climate Change Assessment. University of California, Santa Cruz

Laymon, S.A. 1988. The ecology of the spotted owl in the central Sierra Nevada, California. PhD Dissertation., University of California

Lee, D.E. 2018. Spotted Owls and forest fire: a systematic review and meta-analysis of the evidence. Ecosphere 9:e02354. https://doi.org/10.1002/ecs2.2354

Lee, D.E. 2020. Spotted owls and forest fire: Reply. Ecosphere 11:. https://doi.org/10.1002/ecs2.3310

Lee, D.E., and M.L. Bond. 2015. Occupancy of California Spotted Owl sites following a large fire in the Sierra Nevada, California. The Condor 117:228–236. https://doi.org/10.1650/CONDOR-14-155.1

Lee, D.E., M.L. Bond, and R.B. Siegel. 2012. Dynamics of Breeding-Season Site Occupancy of the California Spotted Owl in Burned Forests. The Condor 114:792–802. https://doi.org/10.1525/cond.2012.110147

Lee, D.E., M.L. Bond, M.I. Borchert, and R. Tanner. 2013. Influence of fire and salvage logging on site occupancy of spotted owls in the San Bernardino and San Jacinto Mountains of

Southern California: Fire and Spotted Owl Dynamics. Jour Wild Mgmt 77:1327–1341. https://doi.org/10.1002/jwmg.581

[LEMMA] Landscape Ecology, Modeling, Mapping and Analysis. 2020. GNN (gradient nearest neighbor) Structure Data. https://lemma.forestry.oregonstate.edu/. Accessed 25 Jul 2022

Lesmeister, D.B., S.G. Sovern, R.J. Davis, D.M. Bell, M.J. Gregory, and J.C. Vogeler. 2019. Mixed-severity wildfire and habitat of an old-forest obligate. Ecosphere 10:1–22. https://doi.org/10.1002/ecs2.2696

Levine, J.I., B.M. Collins, Z.L. Steel, P. de Valpine, and S.L. Stephens. 2022. Higher incidence of high-severity fire in and near industrially managed forests. Frontiers in Ecol & Environ fee.2499. https://doi.org/10.1002/fee.2499

Lindenmayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage Logging and its Ecological Consequences. Island Press

Linley, G.D., C.J. Jolly, T.S. Doherty, W.L. Geary, D. Armenteras, C.M. Belcher, R.B. Bird, A. Duane, M.-S. Fletcher, M.A. Giorgis, A. Haslem, G.M. Jones, L.T. Kelly, C.K.F. Lee, R.H. Nolan, C.L. Parr, J.G. Pausas, J.N. Price, A. Regos, E.G. Ritchie, J. Ruffault, G.J. Williamson, Q. Wu, and D.G. Nimmo. 2022. What do you mean, 'megafire'? Global Ecol Biogeogr 1–17. https://doi.org/10.1111/geb.13499

Livezey, K.B. 2009. Range Expansion of Barred Owls, Part I: Chronology and Distribution. The American Midland Naturalist 161:49–56

Long, L.L., and J.D. Wolfe. 2019. Review of the effects of barred owls on spotted owls. Jour Wild Mgmt 83:1281–1296. https://doi.org/10.1002/jwmg.21715

Lutz, J.A., J.W. van Wagtendonk, and J.F. Franklin. 2009. Twentieth-century decline of large-diameter trees in Yosemite National Park, California, USA. Forest Ecology and Management 257:2296–2307. https://doi.org/10.1016/j.foreco.2009.03.009

Lydersen, J.M., B.M. Collins, M. Coppoletta, M.R. Jaffe, H. Northrop, and S.L. Stephens. 2019. Fuel dynamics and reburn severity following high-severity fire in a Sierra Nevada, USA, mixed-conifer forest. fire ecol 15:43. https://doi.org/10.1186/s42408-019-0060-x

MacKenzie, D.I., M.E. Seamans, R.J. Gutiérrez, and J.D. Nichols. 2012. Investigating the population dynamics of California spotted owls without marked individuals. J Ornithol 152:597–604. https://doi.org/10.1007/s10336-010-0544-6

Mallek, C., H. Safford, J. Viers, and J. Miller. 2013. Modern departures in fire severity and area vary by forest type, Sierra Nevada and southern Cascades, California, USA. Ecosphere 4:art153. https://doi.org/10.1890/ES13-00217.1

Mann, M.L., E. Batllori, M.A. Moritz, E.K. Waller, P. Berck, A.L. Flint, L.E. Flint, and E. Dolfi. 2016. Incorporating Anthropogenic Influences into Fire Probability Models: Effects of Human Activity and Climate Change on Fire Activity in California. PLoS ONE 11:e0153589. https://doi.org/10.1371/journal.pone.0153589

Marks-Block, T., F.K. Lake, R. Bliege Bird, and L.M. Curran. 2021. Revitalized Karuk and Yurok cultural burning to enhance California hazelnut for basketweaving in northwestern California, USA. fire ecol 17:6. https://doi.org/10.1186/s42408-021-00092-6

Mazur, K.M., and P.C. James. 2000. Barred Owl (*Strix varia*), version 2.0. In: Rodewald PG (ed) The Birds of North America. Cornell Lab of Ornithology, Ithaca, New York, USA

McGinn, K.A., F.A. Atuo, G.M. Jones, B.K. Hobart, D.J. Tempel, S.A. Whitmore, W.J. Berigan, R.J. Gutiérrez, and M.Z. Peery. 2022. Implications of non-ideal occupancy for the measurement of territory quality. Global Ecology and Conservation 35:e02097. https://doi.org/10.1016/j.gecco.2022.e02097

McGinn, K.A., M.Z. Peery, C.J. Zulla, W.J. Berigan, Z.A. Wilkinson, J.M. Barry, J.J. Keane, and B. Zuckerberg. In review. Breaking heat waves – a climate-vulnerable species uses cooler forest microclimates during. 3

McIntyre, P.J., J.H. Thorne, C.R. Dolanc, A.L. Flint, L.E. Flint, M. Kelly, and D.D. Ackerly. 2015. Twentieth-century shifts in forest structure in California: Denser forests, smaller trees, and increased dominance of oaks. Proc Natl Acad Sci USA 112:1458–1463. https://doi.org/10.1073/pnas.1410186112

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver and Z.-C. Zhao. 2007. Global Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S.,D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Meyer, M.D., D.A. Kelt, and M.P. North. 2005. Nest trees of northern flying squirrels in the Sierra Nevada. Journal of Mammalogy 86:275–280. https://doi.org/10.1644/BEH-110.1

Millar, C.I., and N.L. Stephenson. 2015. Temperate forest health in an era of emerging megadisturbance. Science 349:823–826. https://doi.org/10.1126/science.aaa9933

Miller, G.S. 1989. Dispersal of juvenile northern spotted owls in western Oregon. M.S. Thesis, Oregon State University

Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat selection by Spotted Owls during natal dispersal in Western Oregon. The Journal of Wildlife Management 61:140–150

Miller, J.D., and H. Safford. 2012. Trends in Wildfire Severity: 1984 to 2010 in the Sierra Nevada, Modoc Plateau, and Southern Cascades, California, USA. fire ecol 8:41–57. https://doi.org/10.4996/fireecology.0803041

Miller, M.P., T.D. Mullins, E.D. Forsman, and S.M. Haig. 2017. Genetic differentiation and inferred dynamics of a hybrid zone between Northern Spotted Owls (*Strix occidentalis caurina*) and California Spotted Owls (*S. o. occidentalis*) in northern California. Ecol Evol 7:6871–6883. https://doi.org/10.1002/ece3.3260

Miller, M.P., S.M. Haig, E.D. Forsman, R.G. Anthony, and L. Diller. 2018. Variation in inbreeding rates across the range of Northern Spotted Owls (*Strix occidentalis caurina*): Insights from over 30 years of monitoring data. The Auk 135:821–833. https://doi.org/10.1642/AUK-18-1.1

Moen, C.A., and R.J. Gutiérrez. 1997. California Spotted Owl Habitat Selection in the Central Sierra Nevada. The Journal of Wildlife Management 61:1281. https://doi.org/10.2307/3802127

M-Opinion 37050. 2017. Principal Deputy Solicitor Exercising the Authority of the Solicitor Pursuant to Secretary's Order 3345

MTBS Project (USDA Forest Service/U.S. Geological Survey). 2022. MTBS Data Access: Fire Level Geospatial Data. (1984 - last revised). https://mtbs.gov/direct-download. Accessed 15 Mar 2022

Mueller, R.C., C.M. Scudder, M.E. Porter, R.T. Trotter III, C.A. Gehring, and T.G. Whitham. 2005. Differential tree mortality in response to severe drought: evidence for long-term vegetation shifts: *Drought-induced differential tree mortality*. Journal of Ecology 93:1085–1093. https://doi.org/10.1111/j.1365-2745.2005.01042.x

Munton, T.E., and J.J. Keane. 2022. California Spotted Owl demography study, Sequoia and Kings Canyon National Park, summary results 2016-2022. USDA Forest Service, Pacific Southwest Research Station

Munton, T.E., K.D. Johnson, G.N. Steger, and G.P. Eberlein. 2002. Diets of California spotted owls in the Sierra National Forest

Nemens, D.G., J.M. Varner, and M.C. Johnson. 2019. Environmental effects of postfire logging: an updated literature review and annotated bibliography. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR

Nemeth, N., D. Gould, R. Bowen, and N. Komar. 2006. Natural and experimental West Nile virus infection in five raptor species. Journal of Wildlife Diseases 42:1–13

Nigro, K., and N. Molinari. 2019. Status and trends of fire activity in southern California yellow pine and mixed conifer forests. Forest Ecology and Management 441:20–31

Nimmo, D.G., A.J.R. Carthey, C.J. Jolly, and D.T. Blumstein. 2021. Welcome to the Pyrocene: Animal survival in the age of megafire. Glob Change Biol 27:5684–5693. https://doi.org/10.1111/gcb.15834

North, M.P. 2002. Environmental factors associated with spotted owl reproduction. USDA Forest Service Gen. Tech. Rep. PSW-GTR-183. U.S. Department of Agriculture, Albany, CA

North, M.P. 2012. Riparian zones pose severe wildfire threat. California Forests Spring.

North, M., G. Steger, R. Denton, G. Eberlein, T. Munton, and K. Johnson. 2000. Association of Weather and Nest-Site Structure with Reproductive Success in California Spotted Owls. The Journal of Wildlife Management 64:797. https://doi.org/10.2307/3802750

North, M., B.M. Collins, and S. Stephens. 2012. Using Fire to Increase the Scale, Benefits, and Future Maintenance of Fuels Treatments. Journal of Forestry 110:392–401. https://doi.org/10.5849/jof.12-021

North, M.P., J.T. Kane, V.R. Kane, G.P. Asner, W. Berigan, D.J. Churchill, S. Conway, R.J. Gutiérrez, S. Jeronimo, J. Keane, A. Koltunov, T. Mark, M. Moskal, T. Munton, Z. Peery, C. Ramirez, R. Sollmann, A. White, and S. Whitmore. 2017. Cover of tall trees best predicts California spotted owl habitat. Forest Ecology and Management 405:166–178. https://doi.org/10.1016/j.foreco.2017.09.019

North, M.P., R.A. York, B.M. Collins, M.D. Hurteau, G.M. Jones, E.E. Knapp, L. Kobziar, H. McCann, M.D. Meyer, S.L. Stephens, R.E. Tompkins, and C.L. Tubbesing. 2021. Pyrosilviculture Needed for Landscape Resilience of Dry Western United States Forests. Journal of Forestry 119:520–544. https://doi.org/10.1093/jofore/fvab026

North, M.P., R.E. Tompkins, A.A. Bernal, B.M. Collins, S.L. Stephens, and R.A. York. 2022. Operational resilience in western US frequent-fire forests. Forest Ecology and Management 507:120004. https://doi.org/10.1016/j.foreco.2021.120004

Olson, G.S., R.G. Anthony, E.D. Forsman, S.H. Ackers, P.J. Loschl, J.A. Reid, K.M. Dugger, E.M. Glenn, and W.J. Ripple. 2005. Modeling of Site Occupancy Dynamics for Northern Spotted Owls, with Emphasis on the Effects of Barred Owls. The Journal of Wildlife Management 69:918–932

Parks, S.A., and J.T. Abatzoglou. 2020. Warmer and Drier Fire Seasons Contribute to Increases in Area Burned at High Severity in Western US Forests From 1985 to 2017. Geophysical Research Letters 47:. https://doi.org/10.1029/2020GL089858

Parks, S.A., S.Z. Dobrowski, J.D. Shaw, and C. Miller. 2019. Living on the edge: trailing edge forests at risk of fire-facilitated conversion to non-forest. Ecosphere 10:. https://doi.org/10.1002/ecs2.2651

Peery, M.Z., and R.J. Gutiérrez. 2013. Life-history trade-offs in Spotted Owls: Implications for assessments of territory quality. The Auk 130:132–140

Peery, M.Z., R.J. Gutiérrez, R. Kirby, O.E. Ledee, and W. LaHaye. 2011. Climate change and spotted owls: potentially contrasting responses in the Southwestern United States. Glob Change Biol 18:865–880. https://doi.org/10.1111/j.1365-2486.2011.02564.x

Peterson, A.T., and C.R. Robins. 2003. Using Ecological-Niche Modeling to Predict Barred Owl Invasions with Implications for Spotted Owl Conservation. Conservation Biology 17:1161–1165. https://doi.org/10.1046/j.1523-1739.2003.02206.x

Peterson, D.W., and E.K. Dodson. 2016. Post-fire logging produces minimal persistent impacts on understory vegetation in northeastern Oregon, USA. Forest Ecology and Management 370:56–64. https://doi.org/10.1016/j.foreco.2016.04.004

Phillips, C.E., D.J. Tempel, and R.J. Gutiérrez. 2010. Do California Spotted Owls Select Nest Trees Close to Forest Edges? Journal of Raptor Research 44:311–314. https://doi.org/10.3356/JRR-09-78.1

Preisler, H.K., N.E. Grulke, Z. Heath, and S.L. Smith. 2017. Analysis and out-year forecast of beetle, borer, and drought-induced tree mortality in California. Forest Ecology and Management 399:166–178. https://doi.org/10.1016/j.foreco.2017.05.039

Prichard, S.J., P.F. Hessburg, R.K. Hagmann, N.A. Povak, S.Z. Dobrowski, M.D. Hurteau, V.R. Kane, R.E. Keane, L.N. Kobziar, C.A. Kolden, M. North, S.A. Parks, H.D. Safford, J.T. Stevens, L.L. Yocom, D.J. Churchill, R.W. Gray, D.W. Huffman, F.K. Lake, and P. Khatri-Chhetri. 2021. Adapting western North American forests to climate change and wildfires: 10 common questions. Ecological Applications 31:. https://doi.org/10.1002/eap.2433

Prinn, R., S. Paltsev, A. Sokolov, M. Sarofim, J. Reilly, and H. Jacoby. 2011. Scenarios with MIT integrated global systems model: significant global warming regardless of different approaches. Climatic Change 104:515–537. https://doi.org/10.1007/s10584-009-9792-y

Pyare, S., and W.S. Longland. 2002. Interrelationships among northern flying squirrels, truffles, and microhabitat structure in Sierra Nevada old-growth habitat. Can J For Res 32:1016–1024. https://doi.org/10.1139/x02-002

Rattner, B.A., K.E. Horak, R.S. Lazarus, K.M. Eisenreich, C.U. Meteyer, S.F. Volker, C.M. Campton, J.D. Eisemann, and J.J. Johnston. 2012. Assessment of toxicity and potential risk of the anticoagulant rodenticide diphacinone using Eastern screech-owls (Megascops asio). Ecotoxicology 21:832–846. https://doi.org/10.1007/s10646-011-0844-5

Redford, K.H., G. Amato, J. Baillie J, P. Beldomenico, E.L. Bennett, N. Clum, R. Cook, G. Fonseca, S. Hedges, F. Launay, S. Lieberman, G.M. Mace, A. Murayama, A. Putnam, J.G. Robinson, H. Rosenbaum, E.W. Sanderson, S.N. Stuart, P. Thomas, and J. Thorbjarnarson. 2011. What Does It Mean to Successfully Conserve a (Vertebrate) Species? BioScience 61:39–48. https://doi.org/10.1525/bio.2011.61.1.9

Ridgway, R. 1887. A manual of North American birds. J.B. Lippincott Company, Philadelphia

Ridgway, R. 1914. The Birds of North and Middle America. Government Printing Office, Washington, DC

Roberts, K.N., W.E. Hall, A.J. Shufelberger, M.A. Reno, and M.M. Schroeder. 2017. California Spotted Owl Occupancy On Mixed-Ownership Lands In the Sierra Nevada of California, 2012 Through 2016. Northwestern Naturalist 98:101–116. https://doi.org/10.1898/NWN15-23.1

Roberts, S.L., J.W. van Wagtendonk, A.K. Miles, and D.A. Kelt. 2011. Effects of fire on spotted owl site occupancy in a late-successional forest. Biological Conservation 144:610–619. https://doi.org/10.1016/j.biocon.2010.11.002

Roberts, S.L., D.A. Kelt, J.W. van Wagtendonk, A.K. Miles, and M.D. Meyer. 2015. Effects of fire on small mammal communities in frequent-fire forests in California. Journal of Mammalogy 96:107–119. https://doi.org/10.1093/jmammal/gyu011

Rockweit, J.T., A.B. Franklin, and P.C. Carlson. 2017. Differential impacts of wildfire on the population dynamics of an old-forest species. Ecology 98:1574–1582

Rogers, K.H., Y.A. Girard, L. Woods, and C.K. Johnson. 2016. Avian trichomonosis in spotted owls (Strix occidentalis): Indication of opportunistic spillover from prey. International Journal for Parasitology: Parasites and Wildlife 5:305–311. https://doi.org/10.1016/j.ijppaw.2016.10.002

Roloff, G.J., S.P. Mealey, and J.D. Bailey. 2012. Comparative hazard assessment for protected species in a fire-prone landscape. Forest Ecology and Management 277:1–10. https://doi.org/10.1016/j.foreco.2012.04.015

Safford, H.D., and J.T. Stevens. 2017. Natural range of variation for yellow pine and mixed-conifer forests in the Sierra Nevada, southern Cascades, and Modoc and Inyo National Forests, California, USA. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA

Safford, H.D., A.K. Paulson, Z.L. Steel, D.J.N. Young, and R.B. Wayman. 2022. The 2020 California fire season: A year like no other, a return to the past or a harbinger of the future? Global Ecol Biogeogr 00:1–22. https://doi.org/10.1111/geb.13498

Salim, H., H. Mohd Noor, N.H. Hamid, D. Omar, A. Kasim, C.S. MD Rawi, A.H. Ahmad, and M.R. Zainal Abidin. 2014. Sub-lethal effects of the anticoagulant rodenticides bromadiolone and chlorophacinone on breeding performances of the barn owl (Tyto alba) in oil palm plantations. Slovak Raptor Journal 8:113–122. https://doi.org/10.2478/srj-2014-0013

Salo Sciences, Inc. 2020. California Forest Observatory Data Description Vegetation Structure and Fuels

Sanderfoot, O.V., S.B. Bassing, J.L. Brusa, R.L. Emmet, S.J. Gillman, K. Swift, and B. Gardner. 2021. A review of the effects of wildfire smoke on the health and behavior of wildlife. Environmental Research Letters 16:123003. https://doi.org/10.1088/1748-9326/ac30f6

Schofield, L.N., S.A. Eyes, R.B. Siegel, and S.L Stock. 2020. Habitat selection by spotted owls after a megafire in Yosemite National park. Forest Ecology and Management 478:1–9. https://doi.org/10.1016/j.foreco.2020.118511

Seamans, M.E. 2005. Population biology of the California spotted owl in the central Sierra Nevada. Ph.D. Dissertation, University of Minnesota

Seamans, M.E., and R.J. Gutiérrez. 2007a. Sources of Variability in Spotted Owl Population Growth Rate: Testing Predictions Using Long-Term Mark-Recapture Data. Oecologia 152:57–70

Seamans, M.E., and R.J. Gutiérrez. 2007b. Habitat Selection in a Changing Environment: The Relationship between Habitat Alteration and Spotted Owl Territory Occupancy and Breeding Dispersal. The Condor 109:566–576

Seamans, M.E., R.J. Gutiérrez, and C.A. May. 2002. Mexican Spotted Owl (Strix Occidentalis) Population Dynamics: Influence of Climatic Variation on Survival and Reproduction. The Auk 119:321–334. https://doi.org/10.1093/auk/119.2.321

[Service] United States Fish and Wildlife Service. 2004. Intra-Service Formal Section 7 Consultation/Conference for Issuance of an Endangered Species Act Section 10(a)(1)(B) Permit (TE-088609-0) for the Western Riverside County Multiple Species Habitat Conservation Plan, Riverside County, California. U.S. Department of the Interior, U.S. Fish and Wildlife Service

[Service] United States Fish and Wildlife Service. 2016a. USFWS Species Status Assessment Framework: an integrated analytical framework for conservation. Version 3

[Service] United States Fish and Wildlife Service. 2016b. Species Status Assessment for San Bernardino Flying Squirrel. U.S. Fish and Wildlife Service, Carlsbad, California

[Service] United States Fish and Wildlife Service. 2017. California Spotted Owl (*Strix occidentalis occidentalis*) Conservation Objectives Report. U.S. Fish and Wildlife Service, Sacramento, California

[Service] United States Fish and Wildlife Service. 2019. Species Status Assessment for the California Spotted Owl (*Strix occidentalis occidentalis*), Version 1.0. Sacramento, California

[Service] United States Fish and Wildlife Service. 2020. Intra-Service Biological Opinion and Conference Opinion on the Issuance of a Section 10(a)(1)(B) Incidental Take Permit to Sierra Pacific Industries for a Habitat Conservation Plan for Northern and California Spotted Owl. U.S. Department of the Interior, U.S. Fish and Wildlife Service

Sierra Forest Legacy, Defenders of Wildlife. 2015. Petition to list the California Spotted Owl (*Strix occidentalis occidentalis*) as an Endangered Species

Sleeter, B.M., T.S. Wilson, C.E. Soulard, and J. Liu. 2011. Estimation of late twentieth century land-cover change in California. Environ Monit Assess 173:251–266. https://doi.org/10.1007/s10661-010-1385-8

Sleeter, B.M., T.S. Wilson, E. Sharygin, and J.T. Sherba. 2017. Future Scenarios of Land Change Based on Empirical Data and Demographic Trends. Earth's Future 5:1068–1083. https://doi.org/10.1002/2017EF000560

Smith, D.R., N.L. Allan, C.P. McGowan, J.A. Szymanski, S.R. Oetker, and H.M. Bell. 2018. Development of a Species Status Assessment Process for Decisions under the U.S. Endangered Species Act. Journal of Fish and Wildlife Management 9:302–320. https://doi.org/10.3996/052017-JFWM-041

Smith, R.B., M.Z. Peery, R.J. Gutiérrez, and W.S. LaHaye. 1999. The Relationship between Spotted Owl Diet and Reproductive Success in the San Bernardino Mountains, California. The Wilson Bulletin 111:22–29

Smith, R.B., W.S. LaHaye, R.J. Gutiérrez, and G.S. Zimmerman. 2002. Spatial habitat characteristics of an insular Spotted Owl (*Strix occidentalis*) population in southern California. In: Newton I, Kavanagh R, Olson J, Taylor I (eds) Ecology and conservation of owls. CSIRO Publishing, Collingwood, Victoria, Australia, pp 137–147

Smith, T.F., D.M. Rizzo, and M. North. 2005. Patterns of mortality in an old-growth mixed-conifer forest of the Southern Sierra Nevada, California. Forest Science 51:266–275

Soboroff, J., and M. Koss. 2017. California has approved legal pot, but black market growers thrive. NBC News

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood, and D. Wratt. 2007. Technical Summary. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Sovern, S.G., M. Taylor, and E.D. Forsman. 2011. Nest Reuse by Northern Spotted Owls on the East Slope of the Cascade Range, Washington. Northwestern Naturalist 92:101–106. https://doi.org/10.1898/10-01.1

[SPI] Sierra Pacific Industries. 2021. Habitat Conservation Plan for Northern and California Spotted Owl. Sierra Pacific Industries, Forestland Management Program in the Klamath, Cascade, and Sierra Nevada Mountains, California

[SPI] Sierra Pacific Industries, K.N. Roberts, B.P. Dotters, A.H. Taylor, and E.C. Murphy. 2022. Occupancy, Status and Movement of the California Spotted Owl associated with Forest Management Activities in the Sierra Nevada of California 2012 through 2021.

Stearns, S.C. 1976. Life-History Tactics: A Review of the Ideas. The Quarterly Review of Biology 51:3–47

Steel, Z.L., B.M. Collins, D.B. Sapsis, and S.L. Stephens. 2021. Quantifying pyrodiversity and its drivers. Proceedings of the Royal Society B: Biological Sciences 288:10. https://doi.org/10.1098/rspb.2020.3202

Stephens, S.L., S.W. Bigelow, R.D. Burnett, B.M. Collins, C.V. Gallagher, J. Keane, D.A. Kelt, M.P. North, L.J. Roberts, P.A. Stine, and D.H. van Vuren. 2014. California Spotted Owl, Songbird, and Small Mammal Responses to Landscape Fuel Treatments. BioScience 64:893–906. https://doi.org/10.1093/biosci/biu137

Stephens, S.L., J.D. Miller, B.M. Collins, M.P. North, J.J. Keane, and S.L. Robert. 2016. Wildfire impacts on California spotted owl nesting habitat in the Sierra Nevada. Ecosphere 7:. https://doi.org/10.1002/ecs2.1478

Stephens, S.L., B.M. Collins, C.J. Fettig, M.A. Finney, C.M. Hoffman, E.E. Knapp, M.P. North, H. Safford, and R.B. Wayman. 2018. Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire. BioScience 68:77–88. https://doi.org/10.1093/biosci/bix146

Stephens, S.L., L.N. Kobziar, B.M. Collins, R. Davis, P.Z. Fulé, W. Gaines, J. Ganey, J.M. Guldin, P.F. Hessburg, K. Hiers, S. Hoagland, J.J. Keane, R.E. Masters, A.E. McKellar, W. Montague, M. North, and T.A. Spies. 2019. Is fire "for the birds"? How two rare species influence fire management across the US. Front Ecol Environ 17:391–399. https://doi.org/10.1002/fee.2076

Stephens, S.L., A.L. Westerling, M.D. Hurteau, M.Z. Peery, C.A. Schultz, and S. Thompson. 2020. Fire and climate change: conserving seasonally dry forests is still possible. Front Ecol Environ 18:354–360. https://doi.org/10.1002/fee.2218

Stephens, S.L., S. Thompson, G. Boisramé, B.M. Collins, L.C. Ponisio, E. Rakhmatulina, Z.L. Steel, J.T. Stevens, J.W. van Wagtendonk, and K. Wilkin. 2021. Fire, water, and biodiversity in the Sierra Nevada: a possible triple win. Environ Res Commun 3:081004. https://doi.org/10.1088/2515-7620/ac17e2

Stephens, S.L., A.A. Bernal, B.M. Collins, M.A. Finney, C. Lautenberger, and D. Saah. 2022. Mass fire behavior created by extensive tree mortality and high tree density not predicted by operational fire behavior models in the southern Sierra Nevada. Forest Ecology and Management 518:120258. https://doi.org/10.1016/j.foreco.2022.120258

Stoelting, R.E., R.J. Gutiérrez, W.L. Kendall, and M.Z. Peery. 2015. Life-history tradeoffs and reproductive cycles in Spotted Owls. The Auk 132:46–64. https://doi.org/10.1642/AUK-14-98.1

Swarthout, E.C., and R.J. Steidl. 2001. Flush responses of Mexican spotted owls to recreationists. The Journal of Wildlife Management 65:312–317

Taylor, A.H., L.B. Harris, and C.N. Skinner. 2022. Severity patterns of the 2021 Dixie Fire exemplify the need to increase low-severity fire treatments in California's forests. Environ Res Lett 17:071002. https://doi.org/10.1088/1748-9326/ac7735

Tempel, D.J., and R.J. Gutiérrez. 2013. Relation between Occupancy and Abundance for a Territorial Species, the California Spotted Owl: Spotted Owl Occupancy and Abundance. Conservation Biology 27:1087–1095. https://doi.org/10.1111/cobi.12074

Tempel, D.J., R.J. Gutiérrez, S.A. Whitmore, M.J. Reetz, R.E. Stoelting, W.J. Berigan, M.E. Seamans and M.Z. Peery. 2014a. Effects of forest management on California Spotted Owls: implications for reducing wildfire risk in fire-prone forests. Ecological Applications 24:2089–2106

Tempel, D.J., M.Z. Peery, and R.J. Gutiérrez. 2014b. Using integrated population models to improve conservation monitoring: California spotted owls as a case study. Ecological Modelling 289:86–95. https://doi.org/10.1016/j.ecolmodel.2014.07.005

Tempel, D.J., R.J. Gutiérrez, J.J. Battles, D.L. Fry, Y. Su, Q. Guo, M.J. Reetz, S.A. Whitmore, G.M. Jones, B.M. Collins, S.L. Stephens, M. Kelly, W.J. Berigan, and M.Z. Peery. 2015. Evaluating short- and long-term impacts of fuels treatments and simulated wildfire on an old-forest species. Ecosphere 6:art261. https://doi.org/10.1890/ES15-00234.1

Tempel, D.J., J.J. Keane, R.J. Gutiérrez, J.D. Wolfe, G.M. Jones, A. Koltunov, C.M. Ramirez, W.J. Berigan, C.V. Gallagher, T.E. Munton, P.A. Shaklee, S.A. Whitmore, and M.Z. Peery. 2016. Meta-analysis of California Spotted Owl (*Strix occidentalis occidentalis*) territory occupancy in the Sierra Nevada: Habitat associations and their implications for forest management. The Condor 118:747–765. https://doi.org/10.1650/CONDOR-16-66.1

Tempel, D.J., H.A. Kramer, G.M. Jones, R.J. Gutiérrez, S.C. Sawyer, A. Koltunov, M. Slaton, R. Tanner, B.K. Hobart, and M.Z. Peery. 2022. Population decline in California spotted owls near their southern range boundary. The Journal of Wildlife Management 86:. https://doi.org/10.1002/jwmg.22168

The California Economic Forecast. 2016. California county-level economic forecast 2016-2050. Report for Caltrans

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.B. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. In: Interagency Scientific Committee to Address the Conservation of the. National Park Service, Portland, Oregon

Thompson, C., R. Sweitzer, M. Gabriel, K. Purcell, R. Barrett, and R. Poppenga. 2013. Impacts of rodenticide and insecticide toxicants from marijuana cultivation sites on fisher survival rates in the Sierra National Forest, California. Conservation Letters 0:1–12

[TMTF] Tree Mortality Task Force. 2017. Tree Mortality: Facts and Figures. Tree Mortality Task Force 19:

Tubbesing, C.L., D.L. Fry, G.B. Roller, B.M. Collins, V.A. Fedorova, S.L. Stephens, and J.J. Battles. 2019. Strategically placed landscape fuel treatments decrease fire severity and promote recovery in the northern Sierra Nevada. Forest Ecology and Management 436:45–55. https://doi.org/10.1016/j.foreco.2019.01.010

Van Lanen, N.J., A.B. Franklin, K.P. Huyvaert, R.F. Reiser II, and P.C. Carlson. 2011. Who hits and hoots at whom? Potential for interference competition between barred and northern spotted owls. Biological Conservation 144:2194–2201. https://doi.org/10.1016/j.biocon.2011.05.011

van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fulé, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and T.T. Veblen. 2009. Widespread Increase of Tree Mortality Rates in the Western United States. Science 323:521–524. https://doi.org/10.1126/science.1165000

Van Wagtendonk, J.W., J.A. Fites-Kaufman, H.D. Safford, M.P. North, and B.M. Collins. 2006. Sierra Nevada Bioregion. In: Sugihara N (ed) Fire in California's Ecosystems. University of California Press, pp 264–294

Verner, J., K.S. McKelvey, B.R. Noon, R.J. Gutiérrez, G.I. Gould Jr., and T.W. Beck. 1992. The California spotted owl: a technical assessment of its current status. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA

Verstappen, F.A.L.M., and G.M. Dorrestein. 2005. Aspergillosis in Amazon Parrots After Corticosteroid Therapy for Smoke-inhalation Injury. Journal of Avian Medicine and Surgery 19:138–141. https://doi.org/10.1647/2002-029

Wagenbrenner, J.W., L.H. MacDonald, R.N. Coats, P.R. Robichaud, and R.E. Brown. 2015. Effects of post-fire salvage logging and a skid trail treatment on ground cover, soils, and sediment production in the interior western United States. Forest Ecology and Management 335:176–193. https://doi.org/10.1016/j.foreco.2014.09.016

Wan, H.Y., J.L. Ganey, C.D. Vojta, and S.A. Cushman. 2018. Managing emerging threats to spotted owls: Emerging Threats to Spotted Owls. Jour Wild Mgmt 82:682–697. https://doi.org/10.1002/jwmg.21423

Wan, H.Y., S.A. Cushman, and J.L. Ganey. 2020. The effect of scale in quantifying fire impacts on species habitats. fire ecol 16:9. https://doi.org/10.1186/s42408-020-0068-2

Ward, J.P., and B.R. Noon. 1998. Habitat Selection by Northern Spotted Owls: The Consequences of Prey Selection and Distribution. The Condor 100:79–92. https://doi.org/10.2307/1369899

Waters, J.R., and C.J. Zabel. 1995. Northern flying squirrel densities in fir forests of northeastern California. Journal of Wildlife Management 59:858–866

Weathers, W.W. 1981. Physiological Thermoregulation in Heat-Stressed Birds: Consequences of Body Size. Physiological Zoology 54:345–361

Weathers, W.W., P.J. Hodum, and J.A. Blakesley. 2001. Thermal Ecology and Ecological Energetics of California Spotted Owls. The Condor 103:678–690

Wengert, G.M., J.M. Higley, M.W. Gabriel, H. Rustigian-Romsos, W.D. Spencer, D.L. Clifford, and C. Thompson. 2021. Distribution of trespass cannabis cultivation and its risk to sensitive forest predators in California and Southern Oregon. PLoS ONE 16:e0256273. https://doi.org/10.1371/journal.pone.0256273

Westerling, A.L., and B.P. Bryant. 2008. Climate change and wildfire in California. Climatic Change 87:231–249. https://doi.org/10.1007/s10584-007-9363-z

Whitmore, S. 2009. Habitat use of juvenile California Spotted Owls (Strix occidentalis occidentalis) during the post-fledging dependency period in Northeastern California. California State University, Chico

Wiens, J.D., R.G. Anthony, and E.D. Forsman. 2014. Competitive interactions and resource partitioning between northern spotted owls and barred owls in western Oregon: Competition Between Spotted and Barred Owls. Wild Mon 185:1–50. https://doi.org/10.1002/wmon.1009

Wiens, J.D., K.E. Dilione, C.A. Eagles-Smith, G. Herring, D.B. Lesmeister, M.W. Gabriel, G.M. Wengert, and D.C. Simon. 2019. Anticoagulant rodenticides in *Strix* owls indicate widespread exposure in west coast forests. Biological Conservation 238:108238. https://doi.org/10.1016/j.biocon.2019.108238

Wiens, J.D., K.M. Dugger, D.B. Lesmeister, K.E. Dilione, and D.C. Simon. 2020. Effects of barred owl (*Strix varia*) removal on population demography of northern spotted owls (*Strix occidentalis caurina*) in Washington and Oregon - 2019 annual report. U.S. Geological Survey

Wiens, J.D., K.M. Dugger, J.M. Higley, D.B. Lesmeister, A.B. Franklin, K.A. Hamm, G.C. White, K.E. Dilione, D.C. Simon, R.R. Bown, P.C. Carlson, C.B. Yackulic, J.D. Nichols, J.E. Hines, R.J. Davis, D.W. Lamphear, C. McCafferty, T.L. McDonald, and S.G. Sovern. 2021. Invader removal triggers competitive release in a threatened avian predator. Proc Natl Acad Sci USA 118:e2102859118. https://doi.org/10.1073/pnas.2102859118

Wilbur, S.R. 1987. Birds of Baja California. University of California Press

Wilkinson, Z.A., H.A. Kramer, G.M. Jones, C.J. Zulla, K. McGinn, J.M. Barry, S.C. Sawyer, R. Tanner, R.J. Gutiérrez, J.J. Keane, and M.Z. Peery. In prep. Forest structure and heterogeneity improve prey acquisition and reproductive success for spotted owls in southern California

Williams, A.P., R. Seager, J.T. Abatzoglou, B.I. Cook, J.E. Smerdon, and E.R. Cook. 2015. Contribution of anthropogenic warming to California drought during 2012–2014. Geophys Res Lett 42:6819–6828. https://doi.org/10.1002/2015GL064924

Williams, P.J., R.J. Gutiérrez, and S.A. Whitmore. 2011. Home range and habitat selection of spotted owls in the central Sierra Nevada. The Journal of Wildlife Management 75:333–343. https://doi.org/10.1002/jwmg.62

Wilson, T.M., and E.D Forsman. 2013. Thinning Effects on Spotted Owl Prey and Other Forest-Dwelling Small Mammals. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon

Wood, C.M., V.D. Popescu, H. Klinck, J.J. Keane, R.J. Gutiérrez, S.C. Sawyer, and M.Z. Peery. 2019a. Detecting small changes in populations at landscape scales: a bioacoustic site-occupancy framework. Ecological Indicators 98:492–507. https://doi.org/10.1016/j.ecolind.2018.11.018

Wood, C.M., S.M. Schmidt, and M.Z. Peery. 2019b. Spatiotemporal Patterns of the California Spotted Owl's Territorial Vocalizations. WBirds 50:232–242. https://doi.org/10.21199/WB50.4.2

Wood, C.M., R.J. Gutiérrez, J.J. Keane, and M.Z. Peery. 2020. Early detection of rapid Barred Owl population growth within the range of the California Spotted Owl advises the Precautionary Principle. The Condor 122:duz058. https://doi.org/10.1093/condor/duz058

Xantus, J. 1859. Catalogue of Birds, Collected in the Vicinity of Fort Tejon, California, with a Description of a New Species of Syrnium: With a Description of a New Species of Syrnium. Academy of Natural Sciences, Philadelphia, PA

Yackulic, C.B., J. Reid, R. Davis, J.E. Hines, J.D. Nichols, and E. Forsman. 2012. Neighborhood and habitat effects on vital rates: expansion of the Barred Owl in the Oregon Coast Ranges. Ecology 93:1953–1966

Yackulic, C.B., J. Reid, J.D. Nichols, J.E. Hines, R. Davis, and E. Forsman. 2014. The roles of competition and habitat in the dynamics of populations and species distributions. Ecology 95:265–279

Yakowicz, W. 2018. Legal Cannabis Entrepreneurs in California Get a Rude Awakening: A Thriving Black Market

Young, D.J.N., J.T. Stevens, J.M. Earles, J. Moore, A. Ellis, A.L. Jirka, and A.M. Latime. 2017. Long-term climate and competition explain forest mortality patterns under extreme drought. Ecology Letters 20:78–86. https://doi.org/10.1111/ele.12711

Zabel, C.J., K. McKelvey, and J.P. Ward Jr. 1995. Influence of primary prey on home-range size and habitat-use patterns of northern spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433–439. https://doi.org/10.1139/z95-049

Zabel, C.J., J.R. Dunk, H.B. Stauffer, L.M. Roberts, B.S. Mulder, and A. Wright. 2003. Northern Spotted Owl Habitat Models for Research and Management Application in California (USA). Ecological Applications 13:1027–1040

Zhou, B., C-W. Xia, Z-R. Chen, W-H Deng. 2020. Individual Identification of Male Ural Owls Based on Territorial Calls. Journal of Raptor Research 54:57. https://doi.org/10.3356/0892-1016-54.1.57

Zimmerman, G.S., R.J. Gutiérrez, and W.S. LaHaye. 2007. Finite study areas and vital rates: sampling effects on estimates of spotted owl survival and population trends. Journal of Applied Ecology 44:963–971. https://doi.org/10.1111/j.1365-2664.2007.01343.x

Zulla, C.J., H.A. Kramer, G.M. Jones, J.J. Keane, K.N. Roberts, B.P. Dotters, S.C. Sawyer, S.A. Whitmore, W.J. Berigan, K.G. Kelly, A.K. Wray, and M.Z. Peery. 2022. Large trees and forest heterogeneity facilitate prey capture by California Spotted Owls. Ornithological Applications 124:duac024. https://doi.org/10.1093/ornithapp/duac024

In litteris

Boatner, K. 2022. Wildlife Program Manager, Humboldt-Toiyabe National Forest, United States Forest Service. Email to Lara Enders, Reno Fish and Wildlife Office. June 21, 2022. Subject: CSO – clearcutting and grows.

Chow, J. 2022. Wildlife Biologist, United States Forest Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. July 13, 2022. Subject: Question about some recent nests for the spotted owl.

Chudek, E. 2022. Assistant Wildlife Biologist, Plumas National Forest, United States Forest Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. June 17, 2022. Subject: California spotted owl Protected Activity Centers on the Plumas National Forest.

De Leon Giron, G. 2022. Professor, Universidad Autonoma de Baja California. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. June 29, 2022. Subject: Request for information on spotted owls in Baja California.

Enders, M. 2022. Wildlife Biologist, Nevada Department of Wildlife. Email to Lara Enders, Reno Fish and Wildlife Office. August 5, 2022. Subject: CSO sentence(s).

Erickson, R. 2022. Associate/Biologist, LSA Associates, Inc. Email to Gjon Hazard, Carlsbad Fish and Wildlife Office. June 2, 2022. Subject: Spotted owls in Baja?

Forsman, E. 2018. Peer reviewer, 2019 California Spotted Owl SSA. Email to Dan Russel, Pacific Southwest Region, United States Fish and Wildlife Service.

Hunter, J. 2022. Ecologist, United States Fish and Wildlife Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. July 12, 2022. Subject: Question about recent spotted owl nests in high-severity fire patches.

Keane, J. 2022. Research Ecologist, Pacific Southwest Research Station, United States Forest Service. Slides from a presentation to the Sacramento Fish and Wildlife Office. March 11, 2022. Title: Wildfire and California spotted owl habitat in the Sierra Nevada.

Miller, B. 2022. Team Leader, Forest Plan Revision Team, United States Forest Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. July 28, 2022. Subject: Forest Plan timelines.

Peery, Z. Associate Professor, University of Wisconsin, Madison. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. October 22, 2022. Subject: question about discontinuation of Eldorado study area.

Porras-Peña, M. 2022. Coordinadora Programa Cóndor de California, Parque Nacional Sierra de San Pedro Mártir. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. June 27, 2022. Subject: Question about spotted owl occurrences in Baja mountains.

Sawyer, S. 2022. Partner review of the 2022 California Spotted Owl SSA. Comments submitted September 1, 2022.

Siedel, K. 2022. United States Fish and Wildlife Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. July 13, 2022. Subject: NSO pair GLE0002 and unaffiliated surveying Plaskett Keller.

Tanner, R. Principle and Founder of Tanner Environmental Services, California Spotted Owl expert. Email to Stephanie Eyes, Sacramento Fish and Wildlife Service. June 12th, 2022.

Torres, T. 2022. Wildlife Biologist, Inyo National Forest, United States Forest Service. Email to Stephanie Eyes, Sacramento Fish and Wildlife Office. June 13, 2022. Subject: Map of Inyo NF spotted owl records from CNDDB.

Unitt, P. 2022. Curator, Department of Birds and Mammals, San Diego Natural History Museum. Email to Peter Sanzenbacher, Palm Spring Fish and Wildlife Office. June 7, 2022. Subject: Request for information on spotted owls in Baja California.

Personal communications

Bowers, A. 2022. Shasta-Trinity National Forest, United States Forest Service. Phone call with Stephanie Eyes, Sacramento Fish and Wildlife Office. June 23, 2022.

Schlick, K. and T. Torres. 2022. Wildlife Biologists, Inyo National Forest, United States Forest Service. Phone call with Stephanie Eyes, Sacramento Fish and Wildlife Office. June 8, 2022.

Tanner, R. 2022. Principle and Founder of Tanner Environmental Services, California Spotted Owl expert. Microsoft Teams call with Amber Aguilera, Stephanie Eyes, and Emilie Graves, Sacramento Fish and Wildlife Office. May 20, 2022.

APPENDIX 1

Table A-1. Coastal-southern California burn severity percentages between 1984 and 2021.

Year	Low Severity (ha)	Moderate Severity (ha)	High Severity (ha)	Total (ha)
1984	0.07%	0.08%	0.07%	0.22%
1985	1.07%	1.46%	1.18%	3.72%
1986	0.34%	0.06%	0.01%	0.41%
1987	0.36%	0.22%	0.09%	0.67%
1988	0.16%	0.16%	0.11%	0.43%
1989	0.20%	0.31%	0.37%	0.89%
1990	0.10%	0.08%	0.06%	0.25%
1991	0.02%	0.02%	0.02%	0.06%
1992	0.06%	0.04%	0.04%	0.14%
1993	0.45%	0.40%	0.09%	0.94%
1994	0.32%	0.33%	0.61%	1.26%
1995	0.23%	0.19%	0.08%	0.49%
1996	0.45%	0.40%	0.18%	1.03%
1997	0.25%	0.25%	0.18%	0.68%
1998	0.06%	0.06%	0.03%	0.15%
1999	0.82%	0.99%	0.68%	2.50%
2000	0.14%	0.13%	0.13%	0.40%
2001	0.01%	0.01%	0.01%	0.02%
2002	1.27%	0.97%	0.58%	2.82%
2003	1.14%	1.76%	2.70%	5.59%
2004	0.45%	0.35%	0.10%	0.91%
2005	0.03%	0.03%	0.01%	0.07%
2006	1.78%	1.83%	0.81%	4.42%
2007	1.50%	1.79%	4.36%	7.65%
2008	1.32%	1.50%	0.76%	3.58%
2009	1.25%	1.63%	1.13%	4.01%
2010	0.01%	0.01%	0.00%	0.03%
2011	0.19%	0.08%	0.01%	0.29%
2012	0.05%	0.06%	0.00%	0.11%
2013	0.20%	0.41%	0.30%	0.91%
2014	0.02%	0.03%	0.00%	0.06%
2015	0.44%	0.24%	0.05%	0.73%
2016	2.43%	1.39%	0.28%	4.10%
2017	1.23%	2.23%	0.17%	3.64%
2018	0.19%	0.32%	0.19%	0.70%
2019	0.05%	0.05%	0.01%	0.11%
2020	2.02%	2.37%	1.47%	5.86%
2021	0.01%	0.01%	0.04%	0.06%
TOTAL	**20.70%**	**22.25%**	**16.91%**	**59.87%**

Table A-2. Sierra Nevada burn percentages between 1984 and 2021.

Year	Low Severity (ha)	Moderate Severity (ha)	High Severity (ha)	Total (ha)
1984	0.09%	0.05%	0.03%	0.16%
1985	0.09%	0.02%	0.00%	0.11%
1986	0.07%	0.04%	0.02%	0.13%
1987	0.60%	0.55%	0.35%	1.51%
1988	0.12%	0.08%	0.05%	0.25%
1989	0.11%	0.08%	0.03%	0.21%
1990	0.17%	0.16%	0.21%	0.53%
1991	0.02%	0.01%	0.01%	0.04%
1992	0.15%	0.21%	0.34%	0.70%
1993	0.01%	0.00%	0.00%	0.02%
1994	0.31%	0.25%	0.15%	0.71%
1995	0.03%	0.01%	0.00%	0.04%
1996	0.47%	0.21%	0.10%	0.77%
1997	0.04%	0.03%	0.02%	0.08%
1998	0.03%	0.01%	0.00%	0.04%
1999	0.41%	0.22%	0.11%	0.73%
2000	0.24%	0.20%	0.15%	0.59%
2001	0.20%	0.21%	0.20%	0.60%
2002	0.45%	0.36%	0.34%	1.15%
2003	0.11%	0.06%	0.03%	0.20%
2004	0.11%	0.09%	0.08%	0.28%
2005	0.09%	0.04%	0.01%	0.13%
2006	0.13%	0.06%	0.03%	0.21%
2007	0.21%	0.22%	0.32%	0.76%
2008	0.69%	0.53%	0.38%	1.61%
2009	0.16%	0.08%	0.04%	0.28%
2010	0.13%	0.09%	0.04%	0.26%
2011	0.14%	0.03%	0.01%	0.18%
2012	0.40%	0.31%	0.23%	0.94%
2013	0.93%	0.80%	0.55%	2.29%
2014	0.35%	0.33%	0.49%	1.17%
2015	0.53%	0.45%	0.32%	1.31%
2016	0.14%	0.14%	0.18%	0.46%
2017	0.52%	0.27%	0.14%	0.93%
2018	1.00%	0.72%	0.31%	2.03%
2019	0.25%	0.15%	0.08%	0.48%
2020	2.86%	2.32%	2.14%	7.32%
2021	3.33%	3.08%	6.02%	12.42%
TOTAL	**15.68%**	**12.45%**	**13.50%**	**41.63%**

Table A-3. Sierra Nevada North burn percentages between 1984 and 2021.

Year	Low Severity (ha)	Moderate Severity (ha)	High Severity (ha)	Total (ha)
1984	0.07%	0.04%	0.01%	0.12%
1985	0.01%	0.00%	0.00%	0.01%
1986	0.03%	0.01%	0.00%	0.05%
1987	0.34%	0.27%	0.17%	0.78%
1988	0.02%	0.02%	0.03%	0.07%
1989	0.05%	0.04%	0.02%	0.11%
1990	0.11%	0.07%	0.04%	0.21%
1991	0.00%	0.00%	0.00%	0.00%
1992	0.11%	0.19%	0.47%	0.78%
1993	0.00%	0.00%	0.00%	0.00%
1994	0.39%	0.30%	0.24%	0.93%
1995	0.00%	0.00%	0.00%	0.00%
1996	0.08%	0.03%	0.01%	0.12%
1997	0.02%	0.01%	0.00%	0.04%
1998	0.01%	0.00%	0.00%	0.01%
1999	0.61%	0.32%	0.15%	1.08%
2000	0.27%	0.19%	0.16%	0.62%
2001	0.19%	0.24%	0.26%	0.69%
2002	0.02%	0.01%	0.00%	0.03%
2003	0.00%	0.00%	0.00%	0.00%
2004	0.13%	0.11%	0.10%	0.35%
2005	0.03%	0.01%	0.01%	0.05%
2006	0.08%	0.06%	0.03%	0.17%
2007	0.31%	0.35%	0.55%	1.21%
2008	0.80%	0.56%	0.43%	1.80%
2009	0.11%	0.05%	0.02%	0.18%
2010	0.02%	0.02%	0.01%	0.05%
2011	0.00%	0.00%	0.00%	0.00%
2012	0.65%	0.50%	0.38%	1.53%
2013	0.18%	0.18%	0.12%	0.48%
2014	0.44%	0.38%	0.75%	1.57%
2015	0.03%	0.02%	0.03%	0.08%
2016	0.05%	0.04%	0.03%	0.12%
2017	0.07%	0.04%	0.04%	0.15%
2018	0.77%	0.56%	0.25%	1.58%
2019	0.40%	0.21%	0.12%	0.74%
2020	1.30%	1.33%	2.40%	5.03%
2021	4.72%	4.48%	9.08%	18.27%
TOTAL	**12.40%**	**10.64%**	**15.95%**	**38.99%**

Table A-4. Sierra Nevada South burn severity percentages between 1984 and 2021.

Year	Low Severity (ha)	Moderate Severity (ha)	High Severity (ha)	Total (ha)
1984	0.11%	0.07%	0.05%	0.23%
1985	0.22%	0.04%	0.01%	0.26%
1986	0.13%	0.08%	0.04%	0.26%
1987	0.96%	0.95%	0.61%	2.52%
1988	0.26%	0.16%	0.08%	0.50%
1989	0.19%	0.12%	0.04%	0.35%
1990	0.25%	0.28%	0.44%	0.98%
1991	0.05%	0.03%	0.01%	0.09%
1992	0.22%	0.23%	0.15%	0.59%
1993	0.03%	0.01%	0.00%	0.05%
1994	0.20%	0.18%	0.04%	0.41%
1995	0.07%	0.02%	0.01%	0.09%
1996	1.01%	0.46%	0.22%	1.69%
1997	0.07%	0.05%	0.04%	0.15%
1998	0.07%	0.02%	0.00%	0.09%
1999	0.13%	0.08%	0.05%	0.26%
2000	0.20%	0.21%	0.13%	0.54%
2001	0.20%	0.16%	0.12%	0.48%
2002	1.05%	0.86%	0.80%	2.72%
2003	0.26%	0.14%	0.07%	0.48%
2004	0.08%	0.06%	0.04%	0.18%
2005	0.16%	0.07%	0.02%	0.25%
2006	0.19%	0.05%	0.01%	0.25%
2007	0.08%	0.03%	0.01%	0.12%
2008	0.54%	0.49%	0.31%	1.34%
2009	0.24%	0.12%	0.06%	0.42%
2010	0.28%	0.19%	0.08%	0.55%
2011	0.33%	0.06%	0.03%	0.42%
2012	0.05%	0.04%	0.02%	0.11%
2013	1.98%	1.68%	1.15%	4.81%
2014	0.22%	0.25%	0.13%	0.61%
2015	1.23%	1.05%	0.73%	3.01%
2016	0.27%	0.29%	0.38%	0.94%
2017	1.14%	0.60%	0.28%	2.03%
2018	1.31%	0.95%	0.40%	2.67%
2019	0.05%	0.06%	0.01%	0.11%
2020	5.05%	3.71%	1.77%	10.53%
2021	1.39%	1.12%	1.75%	4.26%
TOTAL	**20.26%**	**14.98%**	**10.09%**	**45.32%**

Table A-5. Yearly burn severity percentages for high severity for all Analysis Units.

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
1984	0.01%	0.24%	---	0.15%	---	0.01%	0%	---	0.08%	0.16%	0.03%	0%	0%	---	0%	0.04%
1985	1.88%	0.02%	---	---	---	0%	2.67%	---	---	---	0%	0.01%	0%	---	0.02%	0.35%
1986	---	---	---	0.06%	---	---	0.05%	---	0.01%	0%	0.02%	0.15%	---	---	0%	0.02%
1987	0.08%	0.29%	---	0.25%	---	0.02%	0.00%	0%	0.02%	---	0.15%	0%	2.30%	0.23%	0.06%	0.28%
1988	0.01%	0.02%	---	---	---	---	0.37%	---	0.14%	0.03%	0.10%	0.06%	0.12%	0.12%	0.23%	0.07%
1989	0.02%	1.83%	---	---	---	---	0.12%	0.08%	0.02%	---	---	0.13%	---	---	0.01%	0.13%
1990	0.02%	0.30%	---	---	---	0.13%	0.01%	0.01%	---	1.07%	0.06%	0.07%	0.27%	---	1.03%	0.17%
1991	0.05%	---	---	---	---	---	---	---	0.01%	---	---	---	---	---	0.18%	0.01%
1992	0.01%	---	0.99%	---	1.31%	1.06%	0.19%	---	---	---	0.01%	0%	0.46%	---	---	0.25%
1993	0.18%	0.11%	---	---	---	---	---	---	0.01%	---	0.03%	---	0.00%	---	---	0.03%
1994	0.01%	0.03%	0.03%	0.50%	---	0.04%	3.20%	0.01%	0.15%	0.03%	---	0.07%	0.02%	0.79%	0.05%	0.29%
1995	0.02%	0.18%	---	---	---	---	0.01%	---	0.15%	---	0.06%	---	---	---	---	0.02%
1996	0.09%	---	---	0.03%	---	---	0.68%	0.03%	0.11%	0.04%	0.37%	0%	0.28%	---	1.39%	0.12%
1997	0.10%	0%	---	---	---	0.01%	0.33%	---	0.31%	0.14%	0.01%	---	---	---	0.02%	0.06%
1998	0.08%	0.01%	---	---	---	0%	---	---	---	0%	0%	---	---	---	0%	0.01%
1999	0.00%	0.69%	---	---	---	0.13%	1.30%	0.39%	1.23%	0.06%	0.04%	---	0.12%	0.06%	0.02%	0.28%
2000	---	0.43%	---	---	---	0.19%	0.30%	0.43%	---	0.52%	---	---	---	---	---	0.15%
2001	---	0%	0.24%	0.63%	---	0.19%	---	0.07%	0.02%	0.05%	0%	0.05%	0.29%	0.43%	0.21%	0.14%
2002	0.39%	1.48%	0.01%	0.17%	5.28%	0.01%	---	---	0.59%	2.61%	0%	---	---	---	0.02%	0.41%
2003	0.96%	9.68%	---	---	0.03%	---	0.01%	---	2.04%	0.11%	0.05%	---	0.10%	---	0.17%	0.82%
2004	0.18%	0.07%	0.59%	---	---	0%	---	---	0.09%	0.07%	---	---	0.06%	---	0.14%	0.09%
2005	0%	---	---	---	---	0%	---	---	0.02%	0.01%	0.15%	---	---	0.05%	0.01%	0.01%
2006	1.78%	0.22%	0.03%	0.01%	---	0.02%	---	0.04%	0.35%	0.04%	---	0%	0%	0.06%	0.02%	0.26%
2007	9.78%	2.73%	0.11%	---	---	0.01%	---	2.07%	0.61%	0.03%	---	---	---	---	0%	1.51%
2008	0.07%	0.01%	---	---	---	0.84%	4.00%	0.52%	0.10%	0.82%	0.09%	0.19%	0.15%	0.27%	0.01%	0.49%
2009	0.45%	---	---	---	---	0.06%	---	---	3.67%	0.02%	---	---	0.09%	0.02%	0.40%	0.36%
2010	0.01%	---	---	0.03%	---	---	---	0.02%	---	0.30%	0.01%	---	---	0.01%	0.00%	0.03%
2011	0.02%	0.03%	---	---	---	---	---	---	0%	0.07%	0%	0.01%	0.04%	---	0%	0.01%
2012	0.56%	0.12%	---	---	---	0.05%	---	---	0.24%	0.03%	---	0.25%	3.16%	0.47%	3.61%	0.48%

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
2013	0.56%	0.12%	---	---	---	0.05%	---	---	0.24%	0.03%	---	0.25%	3.16%	0.47%	3.61%	0.48%
2014	---	---	3.75%	---	---	0.36%	---	---	0.01%	0.08%	0%	0.27%	0.03%	---	0.44%	0.35%
2015	---	---	---	0.18%	---	---	0.06%	0.03%	0.15%	1.33%	0.06%	0.63%	0.80%	0.06%	---	0.24%
2016	0.17%	---	0.13%	---	---	0.04%	0.73%	---	0.33%	1.48%	---	0%	---	---	0%	0.21%
2017	0.35%	0.02%	---	---	0.06%	---	0.03%	0.17%	0.12%	0.57%	---	0.27%	0.14%	---	0.39%	0.15%
2018	0%	0.57%	---	0.02%	0.08%	0.67%	---	0.20%	0.33%	0.02%	0.01%	0.45%	0.92%	0.04%	0.45%	0.28%
2019	0.01%	---	0.01%	---	---	---	---	0.47%	0.02%	---	---	0.04%	---	---	---	0.06%
2020	0.39%	0.03%	0.01%	0.24%	0.35%	0.50%	4.54%	8.76%	1.99%	1.77%	0.35%	4.61%	---	0%	0.03%	1.94%
2021	---	---	7.96%	3.39%	---	11.31%	0.23%	16.53%	---	4.90%	5.22%	---	---	---	---	4.09%

Table A-6. Yearly burn severity percentages for moderate severity for all Analysis Units.

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
1984	0.02%	0.21%	---	0.16%	---	0.07%	0.09%	0.02%	0.07%	0.21%	0.10%	0.01%	0.01%	---	0.04%	0.06%
1985	2.20%	0.09%	---	---	---	0%	3.49%	---	---	0.08%	0.03%	0.06%	0%	---	0.05%	0.44%
1986	0.01%	0.02%	---	0.19%	---	---	0.16%	---	0.09%	0%	0.03%	0.28%	---	---	0.05%	0.05%
1987	0.26%	0.49%	0%	0.40%	---	0.18%	0.01%	0.55%	0.11%	---	0.34%	0.08%	3.44%	0.19%	0.18%	0.45%
1988	0.08%	0.04%	---	---	---	0%	0.12%	---	0.38%	0.06%	0.21%	0.14%	0.27%	0.08%	0.23%	0.10%
1989	0.01%	1.50%	---	---	---	---	0.09%	0.16%	0.05%	---	---	0.44%	---	---	0.01%	0.15%
1990	0.06%	0.29%	---	---	---	0.21%	0.02%	0.02%	---	0.48%	0.12%	0.09%	0.32%	---	0.60%	0.13%
1991	0.03%	---	---	---	---	---	---	---	0.05%	0%	0%	---	---	---	0.35%	0.01%
1992	0.03%	---	0.44%	---	1.77%	0.42%	0.17%	---	---	0.01%	0.04%	0.02%	0.68%	---	---	0.16%
1993	0.61%	0.67%	---	---	---	---	---	---	0.17%	---	0.09%	---	0%	---	0.01%	0.12%
1994	0.06%	0.18%	0.03%	0.96%	---	0.14%	0.88%	0.02%	0.45%	0.45%	---	0.14%	0.04%	0.77%	0.13%	0.27%
1995	0.04%	0.22%	---	---	---	---	0.11%	0%	0.44%	0.01%	0.16%	---	---	---	---	0.06%
1996	0.61%	0.01%	---	0.20%	---	---	0.73%	0.07%	0.16%	0.15%	0.40%	0.02%	0.78%	---	2.57%	0.27%
1997	0.11%	0.02%	---	---	---	0.02%	0.16%	0.03%	0.68%	0.14%	0%	---	---	---	0.14%	0.09%
1998	0.10%	0.13%	---	---	---	0.01%	---	---	---	0.04%	0.04%	---	---	---	0.04%	0.02%
1999	0%	0.27%	---	---	---	0.29%	3.15%	0.86%	1.49%	0.06%	0.15%	---	0.15%	0.08%	0.13%	0.45%
2000	0.04%	0.47%	---	---	---	0.32%	0.16%	0.37%	---	0.82%	---	---	---	---	---	0.18%
2001	---	0%	0.13%	0.97%	---	0.21%	0%	0.08%	0.04%	0.09%	0.01%	0.10%	0.36%	0.30%	0.28%	0.15%
2002	0.64%	1.70%	0.02%	0.03%	4.48%	0.02%	0.01%	---	1.59%	2.93%	0.01%	---	---	---	0.07%	0.54%
2003	0.51%	2.51%	---	---	0.21%	---	0.04%	---	4.18%	0.18%	0.22%	---	0.21%	---	0.26%	0.56%
2004	0.34%	0.72%	0.62%	---	---	0.02%	---	---	0.34%	0.07%	---	---	0.08%	---	0.31%	0.17%
2005	0.05%	---	---	---	---	0.01%	---	---	0.04%	0.07%	0.50%	---	---	0.04%	0.06%	0.03%
2006	3.59%	0.92%	0.06%	0.04%	---	0.02%	---	0.07%	1.16%	0.14%	0.02%	0.01%	0.02%	0.09%	0.12%	0.58%
2007	2.26%	3.89%	0.07%	---	---	0.01%	---	1.32%	0.83%	0.13%	---	---	---	---	0.02%	0.68%
2008	0.28%	0.09%	---	---	---	0.96%	7.08%	0.82%	0.48%	0.80%	0.33%	0.60%	0.32%	0.35%	0.10%	0.82%
2009	0.64%	---	---	---	0%	0.15%	---	---	5.34%	0.08%	---	---	0.14%	0.04%	0.92%	0.54%
2010	0.04%	---	---	0.05%	---	0%	---	0.08%	---	0.71%	0.08%	---	---	0.01%	0%	0.07%
2011	0.13%	0.17%	---	---	---	---	---	---	0.01%	0.13%	0.01%	0.01%	0.08%	---	0.05%	0.04%

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
2012	---	0.08%	---	---	---	0.85%	---	0.97%	0.17%	0.09%	---	---	0.03%	0.05%	0.07%	0.23%
2013	0.58%	0.70%	---	---	---	0.11%	---	---	0.23%	0.06%	---	0.49%	4.44%	0.64%	5.38%	0.69%
2014	---	---	1.74%	---	---	0.28%	---	---	0.13%	0.22%	0.03%	0.46%	0.15%	---	0.39%	0.24%
2015	---	0%	0%	0.16%	---	---	0.09%	0.02%	0.87%	1.85%	0.32%	1.10%	0.95%	0.03%	---	0.39%
2016	0.73%	0%	0.14%	---	---	0.04%	3.40%	---	1.98%	1.02%	---	0.10%	---	---	0.02%	0.51%
2017	5.37%	0.08%	---	---	0.75%	---	0.29%	0.14%	0.51%	1.16%	---	0.44%	0.35%	0%	1.05%	0.85%
2018	0.01%	1.05%	---	0.05%	0.30%	1.57%	0%	0.41%	0.45%	0.07%	0.09%	1.75%	1.40%	0.02%	1.03%	0.60%
2019	0.04%	---	0.10%	---	---	---	---	0.76%	0.11%	---	---	0.21%	---	---	---	0.12%
2020	0.72%	0.30%	0.03%	0.58%	3.39%	0.47%	4.16%	4.56%	5.01%	4.27%	1.09%	8.72%	---	0.01%	0.14%	2.34%
2021	---	---	4.47%	1.41%	---	5.29%	0.07%	8.18%	---	2.92%	4.01%	---	---	---	---	2.05%

Table A-7. Yearly burn severity percentages for low severity for all Analysis Units.

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
1984	0.03%	0.14%	---	0.20%	---	0.18%	0.14%	0.03%	0.04%	0.27%	0.23%	0.02%	0.01%	---	0.17%	0.08%
1985	1.43%	0.11%	---	---	---	0.02%	2.89%	---	---	0.57%	0.20%	0.10%	0%	---	0.31%	0.38%
1986	0.12%	0.96%	---	0.38%	---	---	0.32%	---	0.22%	0%	0.06%	0.31%	---	---	0.52%	0.15%
1987	0.44%	0.68%	0%	0.44%	---	0.28%	0.30%	0.72%	0.07%	---	0.38%	0.15%	3.26%	0.20%	0.63%	0.53%
1988	0.12%	0.06%	---	---	---	0.04%	0.09%	---	0.34%	0.13%	0.24%	0.23%	0.41%	0.06%	0.46%	0.13%
1989	0.02%	0.94%	---	---	---	---	0.03%	0.19%	0.06%	---	---	0.70%	---	---	0.02%	0.14%
1990	0.08%	0.36%	---	---	---	0.35%	0.04%	0.02%	---	0.22%	0.15%	0.12%	0.34%	---	0.90%	0.15%
1991	0.01%	---	---	---	---	---	---	---	0.05%	0%	0.08%	---	---	---	0.56%	0.02%
1992	0.05%	---	0.28%	0.00%	3.06%	0.22%	0.22%	---	---	0.10%	0.11%	0.06%	0.38%	---	---	0.13%
1993	0.65%	0.80%	---	---	---	---	---	---	0.22%	---	0.15%	---	0.03%	---	0.17%	0.14%
1994	0.08%	0.27%	0.02%	0.76%	0%	0.47%	0.41%	0.06%	0.66%	0.34%	---	0.18%	0.11%	0.80%	0.41%	0.31%
1995	0.03%	0.32%	---	---	---	---	0.33%	0%	0.38%	0.13%	0.36%	---	---	---	---	0.09%
1996	0.81%	0.09%	---	0.39%	---	---	0.64%	0.18%	0.06%	0.34%	0.51%	0.09%	1.14%	0%	7.75%	0.46%
1997	0.09%	0.04%	---	---	---	0.04%	0.09%	0.04%	0.76%	0.11%	0.00%	---	---	---	0.51%	0.10%
1998	0.08%	0.14%	---	---	---	0.03%	---	---	---	0.15%	0.16%	---	---	---	0.26%	0.04%
1999	0.01%	0.23%	---	---	---	0.74%	2.66%	1.47%	1.19%	0.01%	0.31%	---	0.16%	0.09%	0.74%	0.53%
2000	0.13%	0.39%	---	---	---	0.49%	0.08%	0.49%	---	0.78%	---	---	---	---	---	0.21%
2001	---	0.01%	0.10%	0.64%	---	0.17%	---	0.06%	0.02%	0.09%	0.08%	0.08%	0.41%	0.28%	0.56%	0.14%
2002	0.69%	1.80%	0.05%	0.02%	6.61%	0.03%	0.12%	---	2.49%	3.24%	0.05%	---	---	---	0.98%	0.69%
2003	0.19%	1.32%	---	---	0.64%	0%	0.05%	---	3.11%	0.28%	0.66%	---	0.31%	---	0.47%	0.41%
2004	0.43%	0.55%	0.65%	---	---	0.07%	---	---	0.73%	0.05%	---	---	0.06%	---	0.66%	0.21%
2005	0.08%	---	---	---	---	0.07%	---	---	0.02%	0.11%	1.09%	---	---	0.04%	0.43%	0.07%
2006	3.99%	0.68%	0.09%	0.07%	---	0.03%	---	0.04%	0.59%	0.26%	0.24%	0.14%	0.05%	0.18%	0.64%	0.61%
2007	1.72%	3.68%	0.05%	---	---	0.01%	---	1.16%	0.64%	0.28%	---	---	---	---	0.16%	0.59%
2008	0.18%	0.49%	---	---	---	1.17%	6.07%	1.37%	0.37%	0.65%	1.16%	0.65%	0.23%	0.53%	0.31%	0.88%
2009	0.81%	---	---	---	0.01%	0.34%	---	---	3.61%	0.23%	---	---	0.26%	0.04%	1.63%	0.48%
2010	0.02%	---	---	0.07%	---	0%	---	0.07%	---	0.91%	0.33%	---	---	0.01%	0.05%	0.09%

Year	Los Padres-Angeles	Cleveland	Eldorado	Humboldt-Toiyabe	Inyo	Lassen	Los Padres	Plumas	San Bernardino	Sequoia	Sequoia Kings Canyon	Sierra	Stanislaus	Tahoe	Yosemite	TOTAL
2011	0.34%	0.35%	---	---	---	---	---	---	0%	1.04%	0.09%	0.01%	0.11%	---	0.30%	0.15%
2012	---	0.08%	---	---	---	1.22%	---	1.12%	0.14%	0.10%	---	---	0.03%	0.07%	0.28%	0.30%
2013	0.24%	0.39%	---	---	---	0.16%	---	---	0.15%	0.06%	---	0.89%	4.55%	0.57%	7.72%	0.72%
2014	---	---	2.28%	---	---	0.17%	---	---	0.08%	0.21%	0.19%	0.31%	0.12%	---	0.50%	0.25%
2015	---	0.24%	---	0.14%	---	---	0.15%	0.02%	1.41%	2.38%	0.86%	1.38%	0.61%	0.06%	0%	0.50%
2016	0.81%	0.04%	0.23%	---	---	0.03%	7.42%	0%	3.10%	0.91%	---	0.08%	---	---	0.19%	0.81%
2017	2.76%	0.14%	---	---	1.10%	---	0.15%	0.28%	0.54%	2.53%	---	0.43%	0.53%	0%	2.96%	0.73%
2018	0%	0.69%	---	0.03%	0.62%	2.01%	---	0.75%	0.23%	0.27%	0.23%	2.53%	1.66%	0.01%	1.14%	0.76%
2019	0.07%	---	0.15%	---	---	---	---	1.47%	0.11%	---	---	0.17%	---	---	---	0.19%
2020	0.45%	1.10%	0.10%	1.19%	6.28%	0.45%	2.60%	4.37%	4.57%	4.49%	2.30%	12.44 %	---	0.03%	0.49%	2.62%
2021	---	---	5.58%	1.09%	---	6.86%	0.04%	6.72%	---	3.06%	6.48%	---	---	---	---	2.16%