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Draft Conservation Strategy for the California Spotted Owl

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Introduction

The California spotted owl (*Strix occidentalis occidentalis*) occurs primarily on public land in the Sierra Nevada mountain range, the mountains of central coastal California, and the peninsular and transverse ranges of southern California. For the last 24 years, the California spotted owl technical assessment has provided the foundation for conservation of the species (Verner et al. 1992). Since the publication of the technical assessment report, new scientific information has emerged, threats to the species have shifted and evolved, and research has indicated many of the California spotted owl populations have experienced declines (Gutierrez et al. 2017, Tempel et al. 2014b, Connor et al. 2013). These factors, and others (e.g. changing environmental conditions), suggest a new approach to California spotted owl conservation is needed. The new approach will build on the foundations established by the California spotted owl technical assessment report as well as the range-wide conservation objectives identified in the U.S. Fish and Wildlife Conservation Objectives Report (USFWS 2017).

This draft California Spotted Owl Conservation Strategy (Conservation Strategy) aims to establish a robust and implementable approach to conservation of the California spotted owl in the near and long term. The Conservation Strategy focuses on National Forest System lands in the Sierra Nevada Ecoregion, which make up the majority of the owls' distribution (figure 1). However, aspects of the Conservation Strategy can, and should, be applied throughout the species' range, and effective implementation will require a multi-agency and multi-ownership collaborative effort.

The Conservation Strategy is founded on scientific information presented in the California spotted owl conservation assessment (Gutierrez et al. 2017) and other foundational scientific documents such as natural range of variation assessments (Safford and Stevens 2017) conducted for the Sierra Nevada Ecoregion. The Conservation Strategy also includes local management experience and expertise and new scientific information. The Conservation Strategy goals, objectives, and conservation measures are also informed by the conservation objectives identified by the US Fish and Wildlife Service and the Service's summary of current and future stressors (USFWS 2017). While the Strategy uses the Conservation Assessment as a starting point, much research has been undertaken or updated since the Assessment was completed, and the Strategy relies heavily on that information, as well as the USFWS Conservation Objectives Report. In particular, this more recent information indicates the necessity to provide a stronger focus on increasing habitat resiliency to address the high threat of severe disturbance to CSO persistence. Therefore, this Strategy has a strong focus on simultaneously balancing strategic retention of key currently high suitable areas while moving habitat and the surrounding landscape to a more resilient state.

Habitat conditions are dynamic. Fires, management actions, habitat development, bark beetle outbreaks, climate change, and other processes constantly rearrange landscape conditions over different spatial and temporal scales. Therefore the goal of this Conservation Strategy is to promote a resilient and dynamic mosaic of habitat conditions that can support owls through time while minimizing the risk of extinction from large and severe disturbances. A thriving owl population will also require minimizing potential adverse effects of management actions and other threats (for example, barred owls) to owls and their habitat and reducing specific mortality factors that may limit population size and resiliency.

The Conservation Strategy is organized into eight main sections. Sections one, two, and three lay out guiding principles, vision and desired conditions, and goals and objectives, respectively, for California spotted owl conservation. The fourth section summarizes owl ecology and threats to the population. The fifth summarizes past, current, and future conditions, including climate; forest structure and composition; and fire regimes. Most of the information in the fourth and fifth sections also exists, in more detail, in the conservation assessment and other scientific syntheses. Additional science has been produced since the conservation assessment was drafted, and the relevant information is included in this document. The sixth section outlines the general approach used to develop conservation measures to meet the goals and objectives discussed in section three. The seventh section provides conservation strategies, specific draft conservation measures and recommendations, and details that may help with implementation. Section eight is a framework for future monitoring and adaptive management to ensure conservation goals are met, new information is considered and incorporated, and future management is adjusted if necessary..

This Conservation Strategy is a living document and should be updated as conditions evolve, new information becomes available, and new tools are developed.

Section 1. Guiding Principles

1. California spotted owls experienced population declines in three of the four intensively studied area within their range between the early 1990s and 2012. Maintaining California spotted owl populations at sustainable levels requires a better understanding of the causes of these declines.
2. Maintaining a well-distributed network of occupied territories across the California spotted owl range will increase meta-population stability and population resilience to the effects of climate change and other environmental stressors. This will depend on the maintaining a sufficient abundance and distribution of owls and a sufficient amount and distribution of suitable habitat to support a sustainable owl population in the near and long term.
3. Emerging threats (for example, barred owl range expansion, mega-fires, climate change) do not primarily explain observed declines at California spotted owl study sites, but may pose as big or bigger threats than what has caused observed declines.
4. Proposed conservation measures to mitigate past (for example, historical logging) and emerging (for example, barred owl range expansion, mega-fires, bark beetle outbreak, climate change) threats to the California spotted owl should be adaptive. Adaptive measures require swift implementation, monitoring, and revision based on monitoring results.
5. Different ecological features are important to the California spotted owl at several spatial scales. The scales of greatest importance, in order of priority, are the nest stand, the protected activity center, and the territory, and these are embedded in overlapping home ranges and the larger landscape. Maintaining and promoting key habitat elements, like cover of large trees, in the protected activity centers and territories is likely to promote species conservation through enhanced occupancy and demographic performance. Increasing habitat restoration and heterogeneity at the territory, home range, and landscape scales is likely to help protect key habitat elements, confer broad-scale habitat resilience, increase quality of foraging habitat, and provide opportunities for recruitment of new territories in the context of dynamic forest conditions.
6. The forests that support the California spotted owl populations are dynamic ecosystems operating at multiple scales, from sub-stand to landscape. They support a range of vegetation

types and structures and shifting functions and processes that vary over space and time. Current forest conditions are generally greatly departed from historical conditions and today's forests are expected to be less resilient to future conditions such as increasing temperatures, changes in precipitation, changes in fire regimes, and increased drought (Stephens et al. 2016). However, even restoration to the natural range of variation is not likely to create forests with resilience to the full range of future conditions. Restoration to the natural range of variation should thus be seen as a stepping stone towards resilient conditions and an, as yet unknown, future range of variation.

7. Monitoring, adaptive management, and further development of conservation targets and measures are necessary to address the remaining uncertainties in California spotted owl ecology and conservation. Key knowledge gaps remain, including viable population sizes and distributions, mortality factor impacts, and how to increase habitat resilience under changing climates. California spotted owl conservation and this Conservation Strategy should be revised and improved as conditions change and new information becomes available.

Section 2. Vision and Desired Conditions

Considering the guiding principles, the vision for the future of the California spotted owl is:

> a thriving (healthy, resilient, and stable) population of owls, well distributed throughout available habitat and interbreeding among populations, with diverse habitat that is resilient to disturbances at multiple scales and over the long term (decades to centuries).

The desired condition listed below will achieve the vision. They are based on the past, current, and future conditions described in section 5.

- Suitable habitat is well distributed and sufficient to support sustainable owl populations. High quality nesting and roosting habitat is available. Habitat is resilient to disturbances and climate change, considering the natural range of variation and recognizing the Sierra Nevada forests are dynamic ecosystems that will support a range of vegetation types and structures that vary over space and time.
- California spotted owl populations are maintained or enhanced throughout their historic range across the Sierra Nevada forests. Owl populations are maintained across the range as habitat is transitioned to be more resilient and as ecosystems in the Sierra Nevada are transitioned from the current situation towards the natural range of variation and eventually towards the future range of variation.
- Non-habitat threats to California spotted owl are minimized.
- California spotted owl and their habitat are managed in an adaptive framework to address existing scientific uncertainty and changing conditions.

Section 3. Goals and Objectives

To achieve the vision and desired conditions discussed above, the following goals and objectives were developed:

Goal 1. Maintain a well-distributed and stable California spotted owl population across the species' range by minimizing impacts of non-habitat threats.

Objective A. Identify California spotted owl mortality and disturbance causes, determine best mechanism for addressing these factors, and reduce mortality and disturbance risk factors.

Objective B. Study potential mechanisms to prevent barred owls from reaching the critical density that would allow exponential expansion of their range and abundance.

Goal 2. Promote and maintain a well-distributed and connected network of high-quality owl habitat across the California spotted owl range by promoting key habitat elements and connectivity.

Objective A. Promote and maintain important existing nesting, roosting, and foraging habitat, and promote development of new nesting, roosting, and foraging habitat in occupied territories.

Objective B. Retain and recruit sufficient large-tree high-canopy cover areas for nesting and roosting at the protected activity center and territory scales and across all spatial scales, particularly where such conditions will be resilient in the future.

Objective C. Retain and recruit large, old, and structurally complex trees and snags.

Objective D. Retain dense tree clusters and clumps of multi-storied tree canopies, interspersed with small gaps.

Objective E. Minimize risk of habitat loss associated with altered disturbance regimes, including altered fire dynamics and increased bark beetle outbreaks.

Goal 3. Increase habitat resilience and resistance to multiple disturbances, considering climate change, to promote California spotted owl persistence.

Objective A. Work with dynamic forest processes (for example, wildfire) and identify biophysical conditions (for example, steep slopes, north-facing aspect) likely to support key California spotted owl habitat elements now and in the future given these processes and conditions.

Objective B. Increase habitat diversity at multiple scales (sub-stand to landscape), including dense, multi-storied stands; open single-strata stands; and early seral habitat.

Objective C. Restore composition, pattern, and structure of understory and overstory vegetation to align with the conditions in which the California spotted owl evolved and persisted historically, while also accounting for projected changes in landscape characteristics.

Objective D. Increase the presence of large trees on the landscape, while decreasing intermediate and small sized trees, to promote more resistant, resilient trees and landscapes.

Objective E. Allow natural disturbance dynamics to shape and maintain resilient forests.

Objective F. Foster climate adaptation of California spotted owls and their habitat to facilitate long-term conservation.

Section 4. California Spotted Owl Ecology and Threats

Geographic Range

The California spotted owl occurs in forests of the western Sierra Nevada, with few locations documented east of the Sierran Crest (Verner et al. 1992). They also occur in southern California and central coastal California, though those populations are not the focus of this Conservation Strategy. The Sierra Nevada population occurs from roughly 1,000 to 7,740 feet in elevation, with 86 percent occurring between 3,000 and 7,000 feet (Verner 1992). In southern California, they are known to occur at elevations up to 8,400 feet (Verner 1992). In the Sierra Nevada Ecoregion, California spotted owls inhabit largely mixed-conifer and yellow pine forests. Approximately 80 to 90 percent of known sites are in these habitats, with some presence in red fir forests (approximately 10 percent) and riparian and hardwood forests (approximately 3 percent; Verner 1992). Thus, the specific habitat recommendations in this Conservation Strategy focus largely on the mixed-conifer and yellow pine habitats in the Sierra Nevada portion of the California spotted owl range. Figure 1 delineates the focal area of this Conservation Strategy.

Within the Sierra Nevada portion of the California spotted owl range, four long-term owl studies provide much of the demographic, population, and habitat use information available for the subspecies (figure 2). Three of the four study areas are on National Forests (Lassen, Eldorado, and Sierra), and one is within the Sequoia and Kings Canyon National Parks. Data collection began in 1986 on the Eldorado and in 1990 on the other three study areas. A fifth study was located on the San Bernardino National Forest in southern California between 1987 and 2000.

Population Trends

California spotted owl populations appear to have declined between the early 1990s and 2012 in the three demographic study areas occurring primarily on National Forest System lands in the Sierra Nevada. Estimates of the total declines in abundance range from 31 percent on the Sierra National Forest to 44 percent on the Plumas-Lassen National Forest to 50 percent on the Eldorado National Forest (Tempel et al. 2014b, Conner et al. 2016). The cause of these observed declines has not been established conclusively. The only population that appeared stable or increasing over the same time period occurs in the Sequoia-Kings Canyon National Park, the only national park included in these studies. While population monitoring on private lands has been more recent, Roberts and others (2017) found that of 45 California spotted owl territories occupied prior to 1996, all 45 were occupied at least once during the recent study period (2012 to 2016).

Differences in population trends between the three national forests and the national park may be related to different past or current forest management strategies (Blakesley et al. 2005, Seamans and Gutierrez 2007, Tempel et al. 2014a, Jones et al. 2017). The disparity may also be due to different levels of restoration of natural disturbance regimes, specifically the restoration of important ecological processes such as fire (Kilgore and Taylor 1979, van Wagtendonk 2007). The Sequoia-Kings Canyon National Park also has giant sequoia groves and a prevalence of oaks that could be contributing to differences in population trends (Blakesley et al. 2010). The demographic study areas had likely not been affected significantly by barred owls (*Strix varia*) or high-severity fire until quite recently (Tempel et al. 2014b). Recent work suggests current declines may be a lag effect from past removal of large trees (and the resulting structural and compositional changes when this removal was followed by a century of fire suppression) and they are likely unrelated to recent or current habitat decline (Jones et al. 2017).

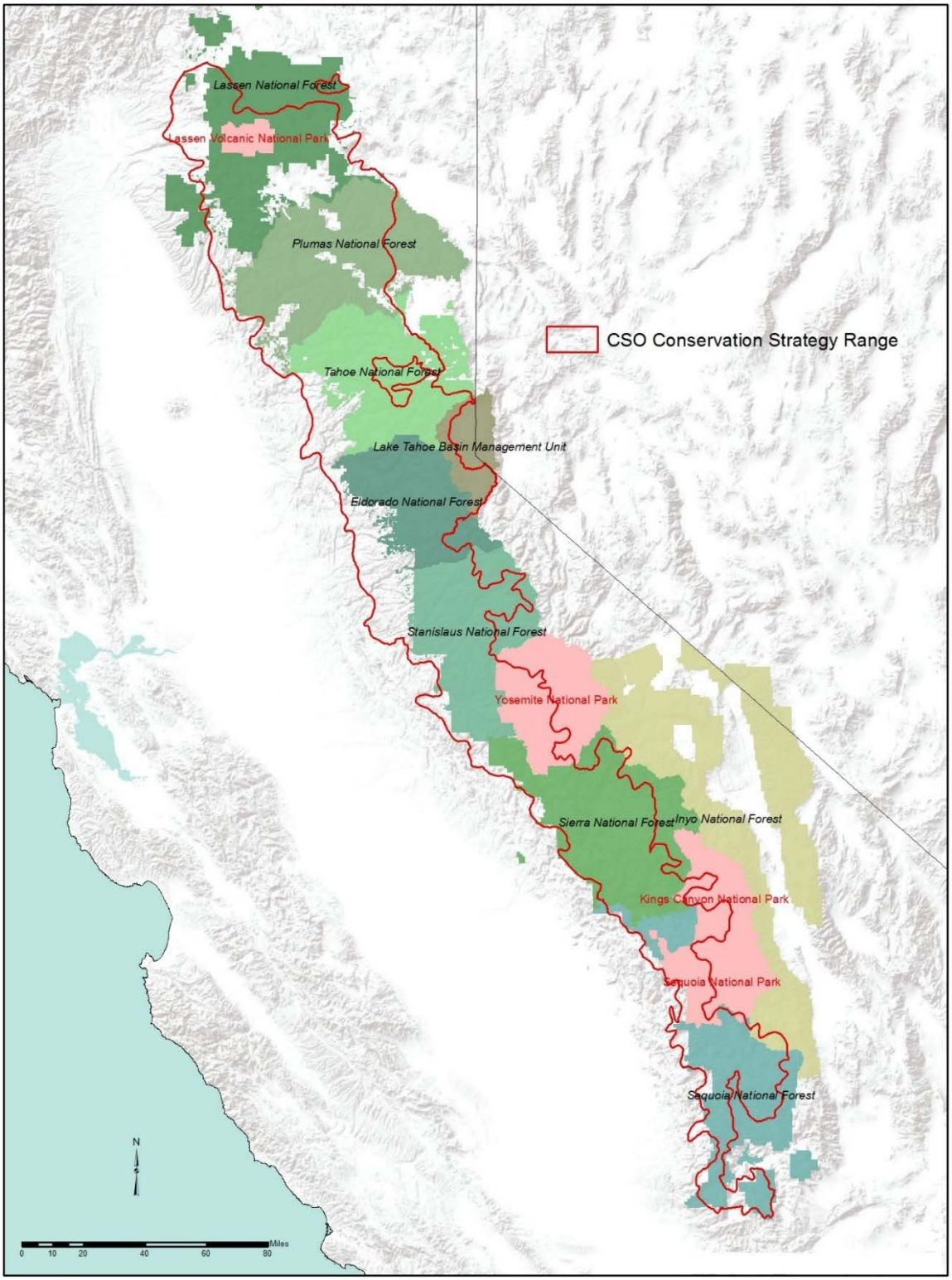

Figure 1. Focal area of the Conservation Strategy

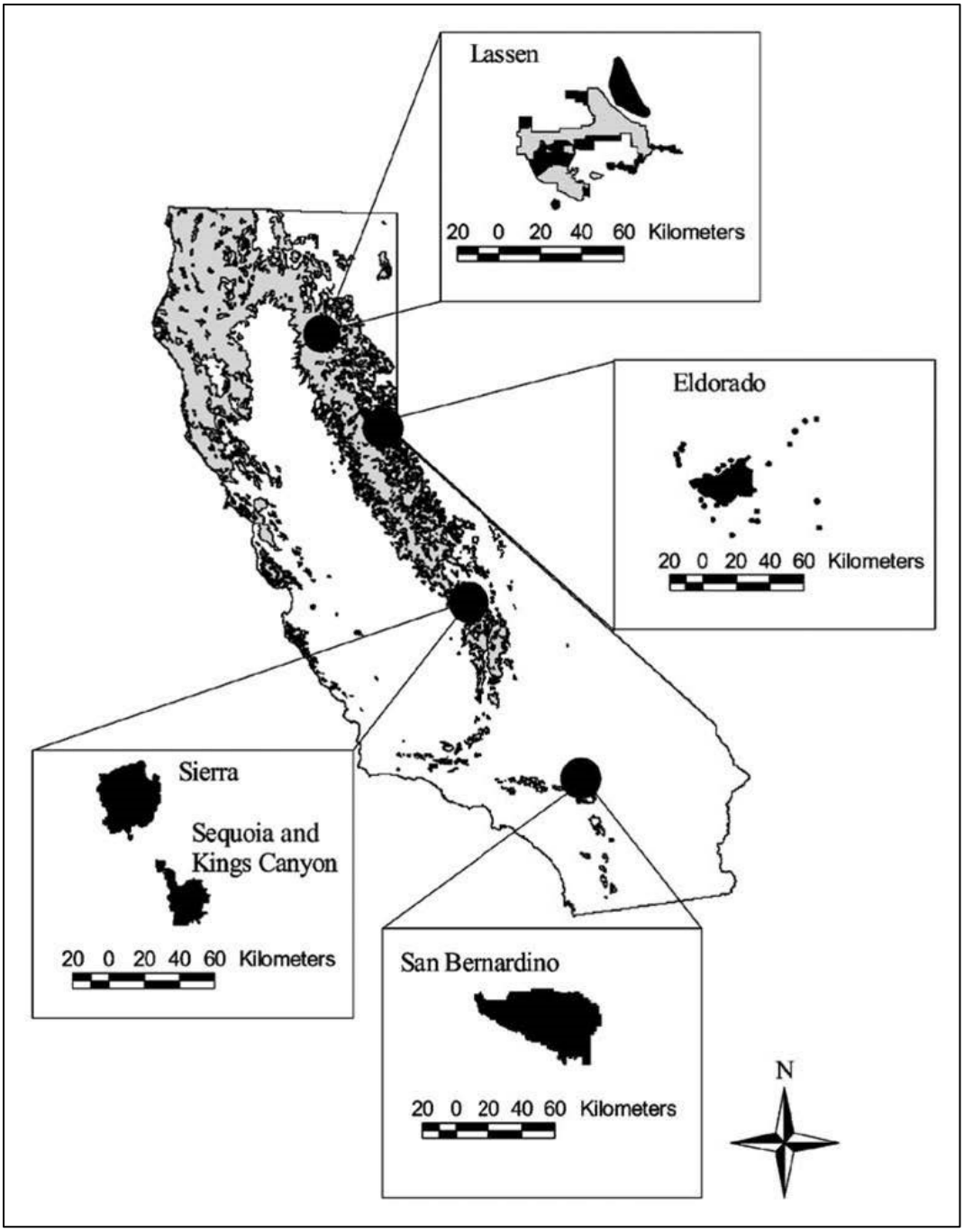

Figure 2. Locations of long-term owl studies (Figure 4-3 in Gutierrez et al. 2017)

California Spotted Owl Ecological Areas of Significance

Core Nesting and Roosting Habitat – Protected Activity Centers

In response to conservation concerns about the California spotted owl, the U.S. Forest Service developed protected activity centers which contain 300 acres (121 hectares) of the best available, contiguous habitat around a nest or roost. These protected activity centers encompass habitat that is most likely essential for nesting and roosting but not for foraging or territorial defense. The

habitat has a closed canopy (at least 60 percent canopy cover) with at least two layers of tree canopy and many large trees and snags (Verner et al. 1992b). Protected activity centers were intended to protect critical habitats at and around nest and roost sites (Verner et al. 1992b) and have been found to generally accommodate spotted owl nesting and roosting activities over the long term – 25 years (Berigan et al. 2012). While 300-acre protected activity centers generally encompass key owl activity, selection for habitat characteristics, like tall tree cover, is greatest within roughly 10 acres of the nest (North et al. 2017).

Under Forest Service land management plans for the last several decades, protected activity centers have been treated as reserve areas, where certain land management activities are generally avoided. California spotted owl use of the landscape over time is not static, and as owls move (abandoning some activity centers and establishing others), the activity center network must change as well. In other words, this reserve network must be dynamic. Ongoing research suggests that the probability of recolonization of a vacant activity center is low (0.34 after one year of vacancy) and declines with time since abandonment (0.10 by 8 years after abandonment; Wood et al. unpublished data; figure 3). By 3 years after abandonment, recolonization probability has declined to 0.24 (Wood et al. unpublished data).

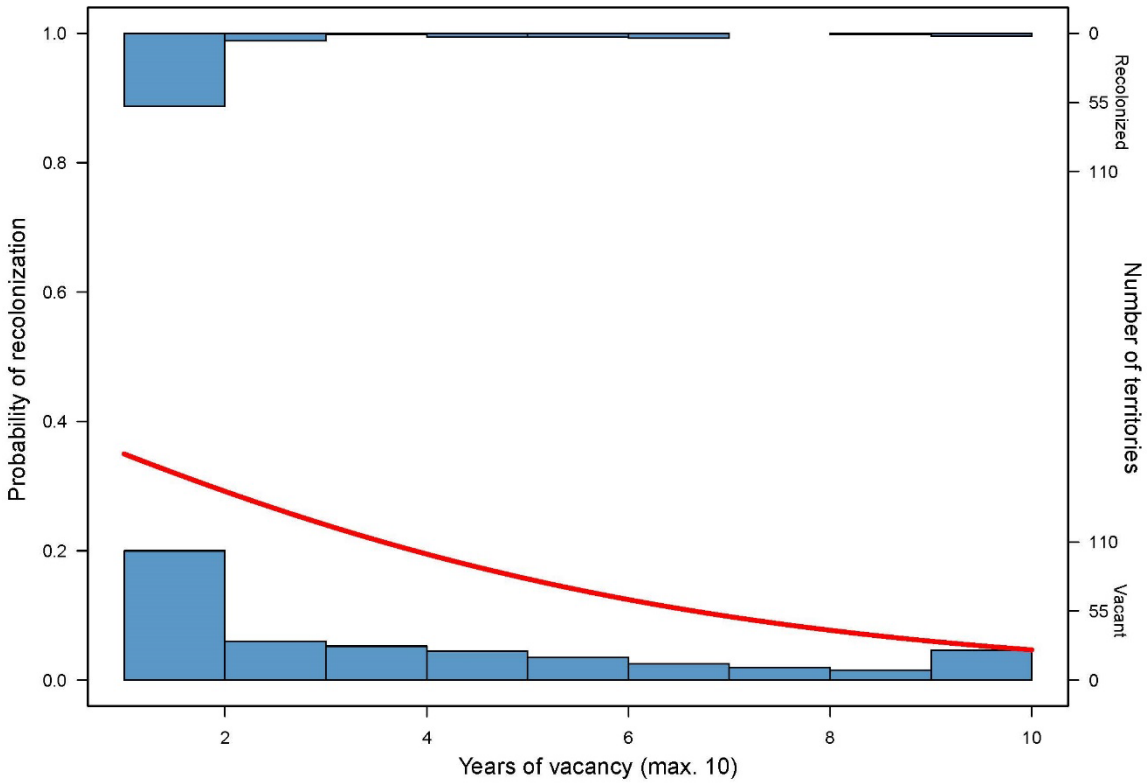

Figure 3. Recolonization probability after abandonment (Wood et al. unpublished data)

Territory

A territory is the area in a home range defended by the resident pair of owls from other owls of the same species (Tempel 2016, Gutierrez et al. 2017). An owl pair's territory is smaller than their home range because not all areas in home ranges are defended against other owls. To date, the precise size and location of spotted owl territories has been estimated in various ways. Core areas are geographic areas in which a pair of territorial owls concentrates nesting, roosting, and foraging activities, and the areas contain critical habitat components (Swindle et al. 1999). Core

area size in the Sierra Nevada likely varies geographically and by ecotype (as is the case with home range size), but geographic variation in core area size has not yet been characterized. Based on radio-marked owls, Bingham and Noon (1997) suggested core area size for California spotted owls was approximately 2,000 acres (813 hectares) in the northern Sierra Nevada. However, Blakesley and others (2005) noted core areas of this size overlap considerably among adjacent owl sites and therefore considered circular analysis areas of approximately 520 acres (203 hectares). This size was based on half the minimum-nearest-neighbor distance between adjacent owl sites. Studies in the central Sierra Nevada have used a radius equal to half the mean-nearest-neighbor distance between the centers of adjacent owl sites (approximately seven tenths of a mile or 1.1 kilometers) which yielded core areas of 1,000 acres (400 hectares) (Seamans et al. 2007, Tempel et al. 2014a, Jones et al. in review). For this Strategy, we define territories in the northern and central Sierra as 1,000 acres, and those in the southern Sierra as 800 Acres (Tempel et al. 2016).

Home Range

A home range is defined as the area used by an individual to meet its life-history requirements and typically includes all nesting, roosting, foraging, and territorial activities within a period of interest (for example, breeding season). Estimates of home range size vary among studies (1,500 to 5,400 acres or 634 to 2,195 hectares), study area (latitude), and individuals. Generally, California spotted owl home ranges are largest in the northern Sierra Nevada and smallest in the southern Sierra Nevada, particularly where oaks (*Quercus* spp.) are the dominant tree type (Zabel et al. 1992). For the purpose of this Strategy, home range is defined as 4,400 acres (figure 4).

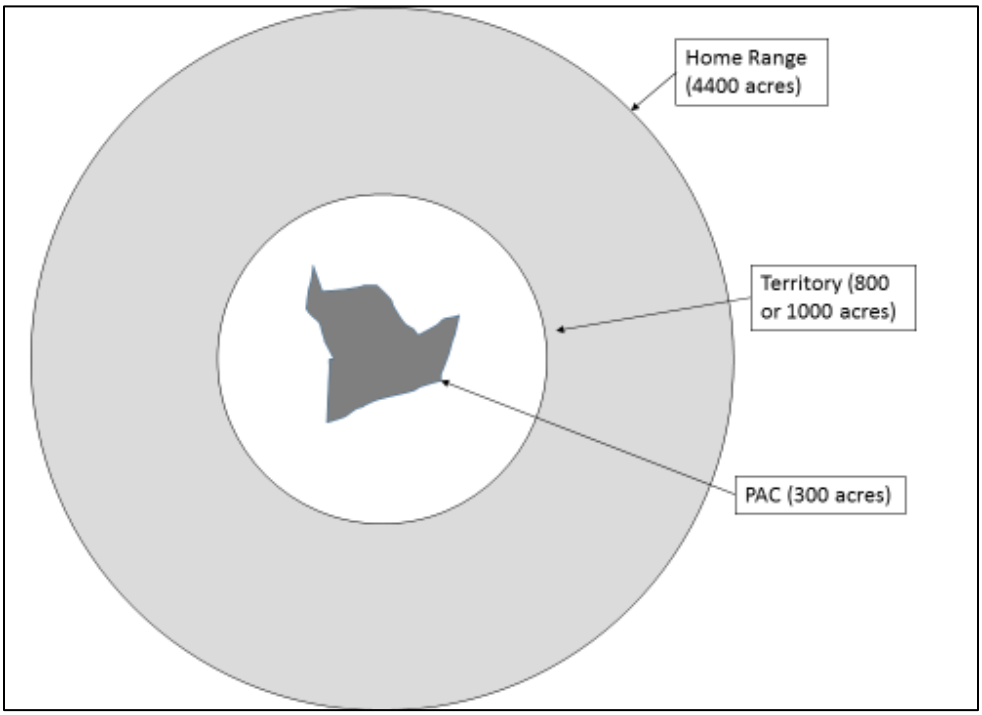

Figure 4. Conceptual model of spotted owl habitat ecological areas of significance.

Habitat Selection

California spotted owls nest in the oldest and largest live and dead trees, especially those having structural defects like cavities, broken tops, and platforms (Verner et al. 1992a, Gutiérrez et al.

1992, North et al. 2000) and those removed from high-contrast edges (Phillips et al. 2010). Average mixed-conifer nest trees are greater than 45 inches in diameter at breast height (USFWS 2017). Three quarters of California spotted owl nests in conifers are in trees larger than 35 inches in diameter at breast height, and ninety percent are in trees larger than 30 inches in diameter at breast height (Keane unpublished data). Nest stands are characterized by high canopy closure and cover (at least 75 percent for both), an abundance of large trees (greater than 24 inches – 61 centimeters – in diameter at breast height), higher-than-average basal area (185 to 350 square feet per acre), an abundance of coarse woody debris, and multiple canopy layers made up of trees of different sizes but dominated by medium-sized trees (12 to 24 inches or 30 to 61 centimeters) (Bias and Gutiérrez 1992, Blakesley et al. 2005, Moen and Gutiérrez 1997, North et al. 2000). Owls select strongly for nest stands with tall tree (more than 160 feet) cover, and tend to avoid areas with gaps or cover in small trees (less than 53 feet; North et al. 2017).

Recent work suggests key habitat characteristics determining occupancy vary across the range, but studies that examined only canopy cover found that both high (more than 70 percent) and moderate (40 to 70 percent) canopy cover are important for occupancy, survival, and productivity (Tempel et al. 2016; J.D. Wolfe and J.J. Keane personal communication). In the northern and central Sierra, high canopy cover was the strongest positive predictor of survival and moderate canopy cover was the strongest positive predictor of productivity, while in the southern Sierra moderate canopy cover was the strongest positive predictor of survival and high canopy cover was the strongest negative predictor of productivity (J.D. Wolfe and J.J. Keane personal communication). The Sequoia-Kings Canyon National Park study area of the southern Sierra was the only study area showing stable population trends. Other studies suggest that intermediate amounts of canopy cover can provide good spotted owl nesting or roosting habitat if large, residual trees are present (Jones et al. 2017, Moen and Gutierrez 1997). When examining the moderate canopy cover category more closely, the amount of area in canopy cover 50 to 59 percent and 60 to 69 percent was found to have more positive association with owl occupancy than 40 to 49 percent (Tempel et al. 2016), though mapping accuracy of these smaller cover categories is much lower than the larger classes. North and others (2017) found that both nest sites and protected activity centers were dominated by the tall tree and co-dominant structure classes, which generally coincided with more than 55 percent canopy cover, but that territories and surrounding landscapes had much more even distributions of structure and cover classes. Finally, while gaps of any size were rare in nest stands, gaps in the protected activity centers, territories, and surrounding landscapes were very similar (North et al. 2017).

One of the most important predictors of occupancy appears to be the intersection of dense canopy cover habitat with large-tree-dominated habitat (Jones et al. 2017, North et al. 2017). Because owls select for cover of tall trees (more than 160 feet) and select against cover of short trees (less than 53 feet), North and others (2017) suggest that the large tree component, rather than canopy cover itself, is likely most important to owl habitat suitability. The Sequoia-Kings Canyon study area showed more large-tree-dominated habitat (both high and moderate canopy cover) and less medium tree-high canopy cover habitat in selected California spotted owl sites (Keane et al. 2016 unpublished report), suggesting large trees play a dominant role in habitat suitability and population stability. Though the large-tree category in most of these studies cannot differentiate between large and very large trees, as it includes all quadratic mean diameters larger than 24 inches, the median quadratic mean diameter in this category was roughly 30 inches in the 2012 dataset used (75.5 centimeters) and reached a maximum of 110 inches (279 cm; Jones et al. 2017) (figure 5). Recent work using more fine-scale vegetation information showed selection for larger tree high canopy cover habitat but selection against small and medium tree high canopy habitat at

higher elevation sites (more than 4,250 feet), and no selection (for or against) such habitat at lower elevations (M. Raphael, personal communication).

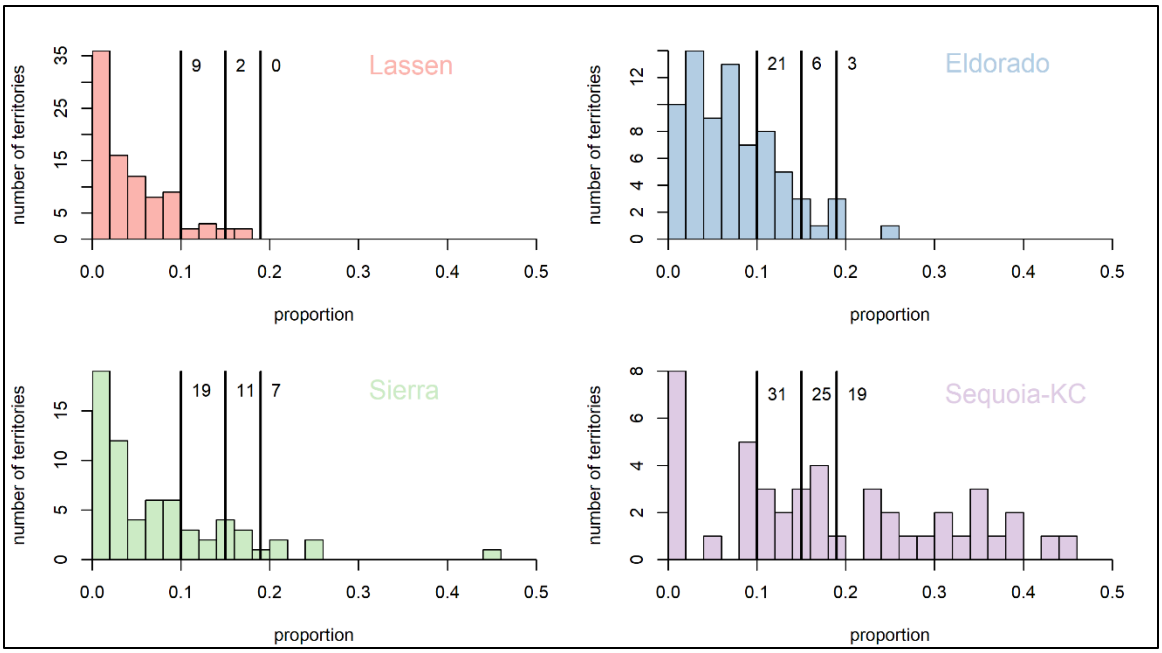

Figure 5. Proportion of large tree - high canopy cover habitat within each territory in the demographic study areas (adapted from Jones et al. 2017)

California spotted owls seem to prefer mature forests with moderate to high canopy cover (at least 40 percent) for foraging as well, but also tend to select edge habitat, particularly fire-created edges (Williams et al. 2011, Eyes 2014, Eyes et al. 2017). Thus, owls may benefit from mature forests with a mosaic of vegetation types and seral stages, which may promote higher prey diversity and abundance by increasing habitat diversity in foraging areas (Zabel et al. 1995, Ward et al. 1998, Franklin et al. 2000, Tempel et al. 2014a). Ongoing work at one site suggests California spotted owls select against areas of low canopy cover (less than 40 percent) within 10 acres (4 hectares) of nest sites, but they are tolerant of low-canopy-cover areas in the protected activity centers (North et al. 2017).

Given this information, for the purpose of this Conservation Strategy, the highest quality nesting and roosting habitat is considered to be habitat dominated by large and very large trees (quadratic mean diameter greater than 24 inches) and high canopy cover (greater than 70 percent cover from remotely sensed data). Additionally, habitat dominated by trees greater than 24 inches diameter at breast height and habitat with greater than 40 percent canopy cover is considered suitable owl habitat, though of lower priority than the highest quality habitat described above. Finally, open areas, areas of low canopy cover (less than 40 percent), and edges interspersed with suitable habitat are considered important for owl foraging and habitat diversity. Habitat types considered potential habitat for the California spotted owl include Sierran mixed conifer, montane hardwood-conifer, montane riparian, ponderosa pine, Jeffery pine, white fir, red fir, eastside pine, lodgepole pine, subalpine conifer, and aspen (CWHR).

Dietary Habits

In the Sierra Nevada, woodrats (*Neotoma* spp.) and northern flying squirrels (*Glaucomys sabrinus*) are the majority of the California spotted owl diet by biomass, although other small

mammals, and a smaller amount of birds, lizards, and insects, are also consumed (Gutiérrez et al. 1995, Munton et al. 1997). Pocket gophers are the second most important food by biomass at both low and higher elevations (Munton et al. 2002).

In the southern Sierra Nevada, woodrats tend to dominate (74 percent by biomass) spotted owl diets in low-elevation, oak woodlands and riparian-deciduous forests and mid-elevation habitats (Laymon 1988, Thrailkill and Bias 1989). Woodrats often occur in more open habitats, oak woodlands, and early-seral-stage forests (Innes et al. 2007). Northern flying squirrels are more important in conifer forests at higher elevations during the breeding season and comprise 46 percent of owls' diets (Munton et al. 2002). Flying squirrels often occur in closed-canopy forests (Pyare and Longland 2002, Meyer et al. 2005, Roberts et al. 2015). Diverse forest conditions are likely to enhance prey habitat at both upper and lower elevations (Sollmann et al. 2016, Jones et al. 2016).

Threats

Altered Disturbance Regimes

Prior to Euro-American settlement, fires in the Sierra Nevada occurred frequently (every 5 to 15 years), generally burned at low to moderate severity (Van de Water and Safford 2011, Mallek et al. 2013, North et al. in review), and maintained low-density stands across much of the landscape. These stands were made up of primarily large, fire-resistant trees (Taylor 2004, Scholl and Taylor 2010, Collins et al. 2011). A century of fire suppression has led to an ingrowth of shade-tolerant (fire intolerant) trees and an accumulation of surface fuels that have increased the frequency and burn patch size of high-severity fires in the Sierra Nevada (Miller et al. 2009, Mallek et al. 2013, Steel et al. 2015). High-severity fires now pose a significant threat to California spotted owls and their habitat, a threat that is expected to increase under most climate change scenarios (see below).

California spotted owls continue to occupy sites that experience low, moderate, and a mixture of fire severities, and likely benefit from the mosaic of habitat created by complex mixed severity fires (Roberts et al. 2011; Lee et al. 2012, 2013). Lee et al. (2012) and Lee et al. (2013) found no significant difference in colonization and extinction probabilities between burned and unburned areas. Lee and Bond (2015a) found high occupancy rates one year following fire. Roberts et al. (2011) found similar occupancy between unburned sites and sites burned at low to moderate severities. Eyes et al. (2017) discovered both selection of lower burn severities and high contrast edges, concluding that sustaining forests burned in a mosaic of lower fire severities in different years, with small proportions of patches burned at high severity, and large unburned patches will benefit spotted owls. These studies support the value of restoring natural levels of disturbance for spotted owl habitat, including a complex mosaic of all fire severities.

There is likely an upper threshold to the amount and patch size of high-severity fire owls can tolerate in their territory (Lee et al. 2012, 2013; Jones et al. 2016; Rockweit et al. 2017), and trends in fire size and severity suggest that this threshold is likely to be surpassed more and more frequently in the future without active restoration (Stephens et al. 2016a). Lee et al. (2012) found that of sites where over 50 percent of suitable vegetation (not 50 percent of overall area) burned at high severity, three of eight became unoccupied. Seamans and Gutierrez (2007) noted lower colonization and higher extinction of territories where 50 acres or more of high canopy cover habitat was lost to logging or fire. In a study where the mean amount of tree cover within the core area that burned at high severity was roughly 60 acres, Lee and Bond (2015b) found that fire was

negatively correlated with site occupancy probabilities. Eyes et al. (2017) found that small patches of high severity fire, less than approximately 90 acres, may benefit spotted owls. Lee et al. (2013) found higher extinction probabilities when approximately 125 acres or more of the core area burned at high severity. Jones et al. (2016) showed that occupancy of severely burned territories declined substantially, and severely burned areas were avoided by owls, even when foraging. Where greater than half of a territory burned at high severity, territory extinction rates went up seven times, and predicted occupancy declined nine-fold from pre-fire values (Jones et al. 2016). A recent study of northern spotted owls similarly detected a negative relationship between the probability of owls surviving and remaining on a territory and the extent and severity of wildfire within a territory (Rockweit et al. 2017). Historic fire regimes likely supported amounts of high severity fire lower than these potential thresholds, with an average fire size of less than 750 acres, less than 10 percent of which (less than 75 acres) burned at high severity (see section 5). On the contrary, current average fire sizes closer to 3,750 acres combined with the average proportion of high-severity fire (29 to 35 percent) and larger, less complex high-severity patches (Stevens et al. 2017) may surpass probable upper thresholds quite frequently (see section 5). Further, trends in high-severity fire proportion and patch size are likely to continue to increase in the absence of active restoration (Stephens et al. 2016a).

Spotted owl habitat is susceptible to high-severity fire because it typically has high vertical and horizontal fuel continuity. From 1993 to 2016, approximately 125,000 acres (22 percent) of owl protected activity centers burned across the range and 32 percent of burned area was high severity (Keane 2017, Keane and Gerrard unpublished data). While this was similar to the burned area on the overall landscape (28 percent) during this period (Keane 2017), it is greater than would be expected under a more natural fire regime (less than 5 to 15 percent of burned area; Mallek et al. 2013) and historic stand conditions. These values do include areas that have re-burned, and areas that burn at high severity once are likely to burn at high severity again. Limiting to forested types only within PACs, approximately 21% of habitat has experienced fire, and roughly 7% of habitat (32% of burned forested area) has experienced high severity fire (Keane and Gerrard unpublished data). High proportions of high-severity fire are also associated with large high-severity patches that are linked to decreases in spotted owl occupancy, colonization, and habitat use (Eyes 2014, Eyes et al. 2017, Roberts et al. 2011, Tempel et al. 2014) and increases in owl extinction probability (Lee et al. 2013). High-severity fire poses an ever increasing risk to California spotted owl habitat in the future, and Stephens and others (2016b) suggest that within the next 75 years, the cumulative amount of nesting habitat burned at high or moderate to high severity (greater than 50 percent basal area mortality) will exceed the total existing habitat today.

Over a century of fire suppression in the Sierra Nevada has resulted in denser, more contiguous and less diverse forests (Hessburg et al. 2005). While these denser forests may be conducive to spotted owl reproductive success in the near term, landscapes with restored fire regimes (for example, Yosemite National Park) show greater small mammal species evenness, which could increase stability and resilience in spotted owl prey populations (Roberts et al. 2015). The Sequoia-Kings Canyon National Park has landscapes with more restored fire regimes and it contains the only study area with a stable California spotted owl population among the four study areas. Contiguous homogenous forests are not sustainable over the long term (Stephens et al. 2016b), and they do not provide the habitat diversity to promote long-term resilience of owl populations and their prey (Kelt et al. 2013).

Drought and insect related tree mortality represent another altered disturbance regime likely affecting the California spotted owl. Drought, particularly the hotter droughts associated with a changing climate, combined with densified forest conditions, have led to severe water stress in

recent years (Asner et al. 2015, Young et al. 2017). This water stress, interacting with insects like bark beetles, pathogens, and air pollution, has led to dramatic increases in tree mortality, especially the large trees on which owls depend. While expected background levels of tree mortality in the mixed conifer habitat are thought to be roughly less than one tree per three acres, significant areas of the landscape have experienced mortality levels of greater than 35 trees per acre between 2014 and 2017 (USDA 2017a). Within the protected activity centers on the Sierra, Sequoia, and Stanislaus National Forests in the Southern Sierra, 55 percent of acres experienced extensive tree mortality of greater than 20 trees per acre between 2014 and 2017 (USDA 2017a). While the response of California spotted owls to this extensive mortality remains, as yet, unknown, it will likely have adverse impacts on spotted owl habitat, since two of the most important habitat elements – large trees and high canopy cover – are significantly reduced by such mortality. Prevention of further habitat loss by reducing water stress and competition will be critical to spotted owl habitat conservation.

Forest Management

The effects of specific forest management activities on spotted owls are not well understood (U.S. Fish and Wildlife Service 2011; Gutierrez et al. 2017). Some activities decrease owl habitat suitability while others may increase it, and some management may cause short term habitat decreases while increasing long-term habitat sustainability in the face of disturbance (Tempel et al. 2015). Both short- and long-term population responses to these various changes are difficult to discern. In particular, small sample sizes have led studies to combine different types of forest management, making it impossible to conclude how different activities may lead to different outcomes. However, there appear to be some general points of agreement among the studies examining effects of forest management on spotted owls. First, mosaic habitat created by mixed severity prescribed or managed fire likely provides benefits to the California spotted owl (Roberts et al. 2011, 2015; Lee et al. 2012, 2013; Eyes et al. 2017). On the other hand, management that creates wide swaths of homogenous open habitat (for example, defensible fuel profile zones) leads to habitat quality declines and resulting avoidance by owls in the near term (Stephens et al. 2014). Similarly, habitat homogenization and densification due to fire suppression has also likely caused habitat loss for California spotted owls (Verner et al. 1992, Gutierrez et al. 2017). Second, mechanical treatment or harvest that significantly increases the amount of low-canopy cover habitat (less than 40 percent cover from remotely sensed data) in spotted owl territories likely negatively impacts California spotted owl occupancy (Tempel et al. 2016). Further, mechanical treatment or harvest that reduces the number of large and very large trees, or decreases the amount of large-tree habitat with moderate or high canopy cover, likely negatively impacts California spotted owl occupancy, survival, and productivity (Jones et al. in review, Tempel et al. 2016, North et al. 2017). On the contrary, given that owls avoid cover in smaller trees (less than 53 feet tall), treatments that reduce these potential ladder fuels likely maintain or improve owl habitat (North et al. 2017). Other results have been more mixed, and largely depend on the scale and type of management activities examined.

Seamans and Gutiérrez (2007) found California spotted owl territories experienced a 2.5 percent decline in territory occupancy probability when more than 50 acres (20 hectares) of mature forest were altered. These alterations were caused by various types of management including clearcutting, thinning, and other prescriptions, or by fire, but specific impacts of different disturbance types could not be examined independently due to sample size. Stephens and others (2014) showed the number of occupied owl territories declined from 7 to 9 before and during implementation of vegetation treatments (2002 to 2007) to four territories 3 to 4 years after treatments were completed, though longer-term impacts or benefits are unknown. Tempel and

others (2014) found mixed results related to the effect of medium-intensity timber harvest on owls, but noted that actions that converted mature conifer forest from high to moderate canopy cover were negatively correlated with demographic parameters. Surprisingly, the authors found that high-intensity timber harvest (such as clear-cutting) appeared to have a weak beneficial effect on owls, likely due to the creation of edges (Tempel et al. 2014).

On the other hand, more recent studies failed to detect any negative impact of logging (mechanical treatment) to California spotted owl occupancy, survival, or productivity (Tempel et al. 2016, Irwin et al. 2015). Tempel and others (2016) found a nonsignificant positive impact of logging on occupancy at the Eldorado National Forest study site. Irwin and others (2015) found most harvests had no detectible effect on spotted owls and did not detect any site abandonment of occupied territories where up to 58 percent of the area was treated. This may be because forest management practices since the early 1990s have not reduced the amount of high-quality habitat found to be most important in determining occupancy over time (Jones et al., in review). In fact, J.D. Wolfe and J.J. Keane (personal communication) were unable to assess effects of logging across the demographic studies over multiple decades because the number and amount of territories affected were so small.

Timber harvesting on a large portion private of lands in the California spotted owl range uses even-aged management, like clear-cutting, which may reduce spotted owl habitat quality by reducing or eliminating critical habitat elements: high canopy cover and old, large-diameter trees and associated large downed logs (McKelvey and Weatherspoon 1992, Gutierrez et al. 2017). However, a recent study suggests California spotted owls may occur on private timberlands at greater density than expected, despite these areas having higher harvest rates. The study also suggests occupancy did not decline over time regardless of harvest (Roberts et al. in press). Additional work is still required to determine the quality of habitats on private lands, their contribution to the viability of the regional spotted owl population, and the long-term effects of even-aged harvest systems. Spotted owls have also been observed avoiding private lands, presumably because of a lack of key habitat elements (Bias et al. 1989).

Taken together, studies on impacts of forest management and disturbance on spotted owl habitat and demography suggest that there may be important tradeoffs in the short- and long-term habitat suitability and sustainability, particularly as climate change increases the frequency and severity of habitat disturbances (Tempel et al. 2015, 2016; Stephens et al. 2016b). A quantitative scenario-based risk assessment is underway to examine these tradeoffs, and results will be incorporated into this Strategy as they become available. Figure 6 below depicts a preliminary illustration of future impacts of high severity fire on owl occupancy in a no-management scenario (preliminary results, subject to change, Jones et al. unpublished data). While forest management that increases heterogeneity and resilience to disturbance may benefit the spotted owl in the short and long term (Roberts et al. 2015, Gutierrez et al. 2017, Tempel et al. 2016, Jones et al. 2016), management that maintains or increases homogeneity (particularly homogenous open areas) or decreases the amount of large tree habitat may come at a near-term cost to current spotted owl occupancy. Potential near-term costs of density- and canopy-reduction treatments may be minimized by maintaining or increasing the highest quality habitat (that is, large-tree habitat; Wood et al., unpublished data) and may be balanced by long-term gains if they result in increased persistence/sustainability of habitat elements over time (Stephens et al. 2014; Tempel et al. 2014, 2015; Jones et al. 2017). Balancing these tradeoffs, and promoting management activities that will maintain or increase key owl habitat elements in more sustainable locations in the future, will require site-specific analysis combined with landscape level planning.

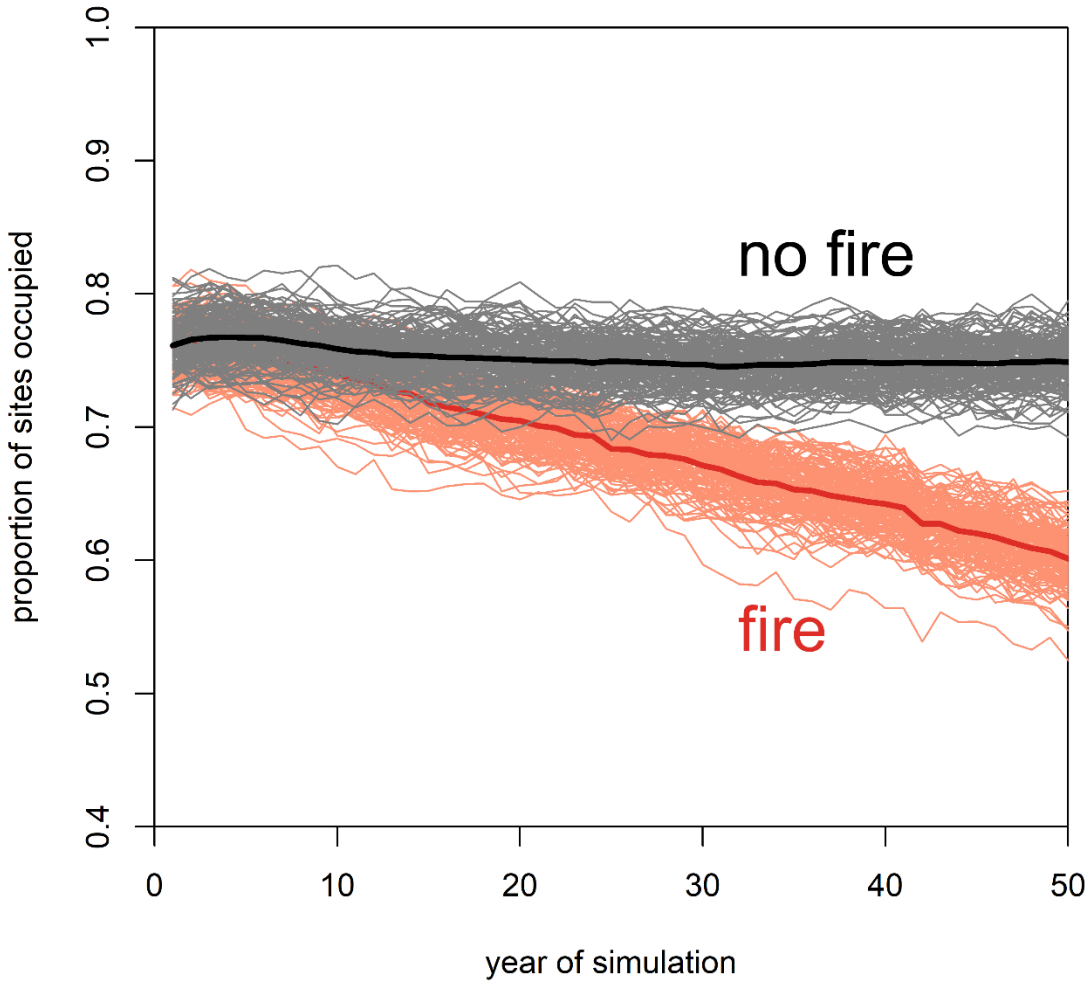

Figure 6. Preliminary depiction of future fire effects on owl site occupancy in a baseline, "no treatment" scenario (subject to change, Jones et al. unpublished data)

Climate Change

Projected changes in climate are an emerging threat to California spotted owls and their forest habitat and may have significant impacts to owl populations in the Sierra Nevada over the coming decades. General climate change model projections for the Sierra Nevada indicate temperatures will increase by 5.4 to 10.8 degrees Fahrenheit (3 to 6 degrees Celsius) during the 21st century. Decreased winter snowpack and increased ecosystem moisture stress are expected, though projections of changes to precipitation patterns are less certain (Cayan et al. 2013).

Increases in temperature and changes in precipitation patterns may impact spotted owls in the following ways:

- direct, physiological effects on individuals

- alterations to prey communities, interactions with predators and competitors, and disease dynamics
- changes in habitat quantity, quality, and distribution

In some parts of the spotted owl's range, drought and high temperatures during the previous summer have been linked to lower survival and recruitment of spotted owls the following year (Franklin et al. 2000, Glenn et al. 2011, Jones et al. 2016). Decreases in precipitation, and associated moisture stress, may reduce production of plants, seeds, and fungi that are important food for spotted owl prey (Seamans et al. 2002; Olson et al. 2004; Glenn et al. 2010 and 2011). Impacts to owl populations are likely to be complex. Warm, dry springs tend to increase reproductive success, and spotted owls have population-specific responses to regional climate and weather patterns (Glenn et al. 2010 and 2011, Peery et al. 2012, Jones et al. 2016).

Climate change projections suggest much of the low- and mid-elevation forests that currently comprise owl habitat in the Sierra Nevada are vulnerable to conversion to woodlands, shrublands, and grasslands. Recent drought (2012 to 2015) led to extensive mortality of trees in California spotted owl habitat, and the extent of the impacts are largely unknown (Asner et al. 2015). Moreover, projected increases in temperature and decreases in snowpack for the Sierra Nevada (Safford et al. 2012) are likely to continue the increasing trend in the size of stand-replacing fires and proportion of landscape impacted by those fires (Stephens et al. 2013). In the long term, these threats may be somewhat mitigated by mixed-conifer forests moving upslope and the development of habitat for owls where none now exists (Peery et al. 2012). However, development of suitable forest structure at higher elevations will likely take many decades and may not keep pace with habitat loss at lower elevations (Stephens et al. 2016b).

Barred Owls

Barred owls have invaded western North America over the past century (Livezey 2009), and they threaten northern spotted owl population viability in many parts of this subspecies' range (U.S. Fish and Wildlife Service 2011, Wiens et al. 2014). Barred owls presently occur in relatively low densities in the Sierra Nevada, but they are expanding their range (Dark et al. 1998, Keane 2014). They may soon colonize large parts of the Sierra Nevada and become a primary threat to the California spotted owl (figure 6) (Gutiérrez et al. 2007, U.S. Fish and Wildlife Service 2011, Wiens et al. 2014).

Barred owls are competitively dominant to spotted owls. They use a broader range of habitats, have a broader diet, have smaller home ranges, and produce more young, leading to much higher potential population densities of barred than spotted owls (Wiens et al. 2014). Interactions between the two species lead to negative impacts on northern spotted owl population (Dugger et al. 2011; Yackulic et al. 2012, 2014; Wiens et al. 2014). When barred owls are present, northern spotted owls have greater territory extinction probabilities, lower colonization probabilities (Olson et al. 2005, Dugger et al. 2011, Yackulic et al. 2014), lower nest success (Wiens et al. 2014), and lower probability of habitat use (Van Lanan et al. 2011). Similar studies have not been conducted on California spotted owls but interactions between barred owls and California spotted owls are likely to be the same.

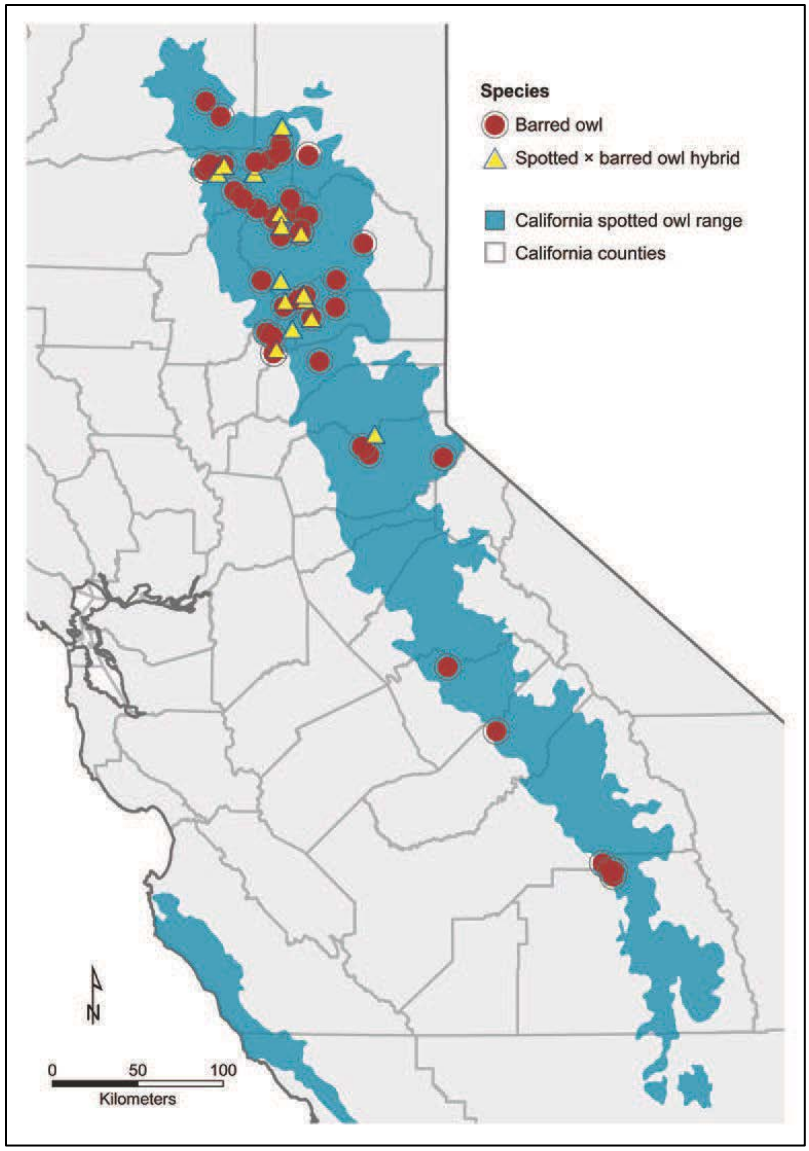

Figure 7. Barred owl and sparred owl records within the range of the California spotted owl in the Sierra Nevada, 1989 to 2013 (figure 7-11 in Gutierrez et al. 2017)

Experimental removal of barred owls in the northern spotted owl range indicate spotted owls re-occupy sites within one year; however, barred owls again displace spotted owls at some sites within 1 to 4 years (Diller et al. 2012). If control measures were implemented in the California spotted owl range now, while barred owl population densities are low, they are likely to be more successful than if implementation is delayed (Dugger et al. 2016, USFWS 2017).

Noise Disturbance

Noise disturbance resulting from human recreation and management activities (for example, noise from chainsaws or motorized vehicles) has the potential to impact California spotted owls, although there is considerable uncertainty about how much and what types of disturbance may be detrimental. Potential wildlife responses to noise disturbance range from behavioral responses, to increased stress levels (as evidenced by hormone levels), to decreased reproduction (due to a

combination of behavioral and hormonal responses). There is little evidence to date that noise disturbance impacts spotted owl reproduction; evidence is mixed about whether and what type of noise disturbance impacts spotted owl stress hormones; and there is evidence of spotted owl behavioral responses to noise disturbance within a certain proximity. Thus, while owls likely tolerate various levels and types of noise disturbance, some disturbance may affect behavior and reproduction. Conservation measures addressing noise disturbance should therefore be type- and distance-specific, and more research is necessary to better inform such measures.

Chainsaws

Delaney and others (1999) found no difference in Mexican spotted owl reproductive success when owls were exposed to helicopter and chainsaw noise. Tempel and Gutierrez (2003) found no hormonal or behavioral responses of male California spotted owls exposed to chainsaw activity roughly 330 feet (100 meters) from their roost site. Delaney and others (1999) found behavioral responses (flushing) only when disturbance (helicopter or chainsaw) was within roughly 350 feet (105 meters) of the nest, although spotted owls did not flush during the incubation and nestling phases of reproduction. Delaney and others (1999) also found effects on prey delivery rates when disturbance was within roughly 315 feet (96 meters) of the nest. Taken together, these studies suggest that limiting chainsaw activity within 100 meters (or roughly 300 feet) of nest sites during the early breeding season will minimize any potential negative impacts on California spotted owls, though owl reproduction is likely resilient to such noise impacts.

Roads, motorized vehicles and helicopters

Hayward and others (2011) found that northern spotted owl closer (less than 100 meters) to low-noise-level roads actually fledged more young than those further away (likely due to increased prey availability around roads), while owls closer to high-noise-level roads fledged fewer young than those further away (likely due to the chronic stress of continuous traffic). Wasser and others (1997) reported higher stress levels (indicated by fecal corticosterone) in male northern spotted owls within one quarter of a mile (0.41 kilometers) of a major logging road or recent timber harvest than those further away, but no differences in female hormone levels were found. The authors did not examine hormonal differences relative to distances within a quarter mile of the roads. Tempel and Gutierrez (2004) found no effect of road proximity on fecal corticosterone levels in California spotted owls. Hayward and others (2011) also did not detect an association between hormone levels and distance to roads, though they observed increased hormone levels with acute (1 hour) exposure to traffic noise, particularly in males during the early breeding season (May). Delaney and others (1999) observed alert behavior in Mexican spotted owls when helicopters averaged roughly 1300 feet (403 meters) above the nest. Taken together, these studies suggest that there may be both benefits and costs associated with roads for California spotted owls, and additional research is needed on if and when road activity negatively impacts owl survival or reproduction. Distance effects are likely site- and road type- specific, as well as sex-specific. However a very conservative approach of limiting excessive acute vehicle traffic (for example, heavy equipment and motorized vehicles for extensive time periods) within a quarter mile of nest sites during the early breeding season may minimize potential negative impacts as more information is gathered.

Contaminants

Environmental contaminants, particularly anticoagulant rodenticides associated with illegal marijuana cultivation, may be an important emerging threat to the California spotted owl. While California spotted owls have not yet been tested for exposure to rodenticides, studies indicate that between 85 and 100 percent of fishers (*Pekania pennanti*), 40 percent of barred owls (of 84

tested), and 7 of 10 northern spotted owls showed exposure (Thompson et al. 2017, Gutierrez et al. 2017, Gabriel et al. 2018). Given that California spotted owls share similar habitats and prey with fisher and northern spotted owls, they are also likely to be affected by rodenticides (Gutierrez et al. 2017). Barred owls eat a wider diversity of prey than either northern or California spotted owl, which may serve to dilute their exposure to anticoagulant rodenticides (Gabriel et al. 2018). Thus, we expect risk to California spotted owls by these contaminant is likely on the higher end, similar to fisher and northern spotted owl. Effects of exposure to anticoagulant rodenticides are not yet well understood in raptor species. Minimal available information has shown that exposure either decreases fitness or increases mortality from what would normally be considered a benign injury (Gabriel et al. 2018). Studies have linked exposure to reduced clutch size, brood size, fledging success, slower clotting time, and contaminant transfer to eggs (Gabriel et al. 2018). Further, given differential exposure rates, contaminant impacts may serve as yet another factor favoring barred owls competitive advantage over spotted owls.

Section 5. Past, Current, and Future Habitat Conditions

Understanding the current state of California spotted owl habitat, as well as the recent changes it has undergone, and the projected changes it is likely to see in the future, is critical to the development of effective habitat conservation measures for the species. Present departures from historic conditions that are specifically relevant to the owl include 1) a lack of forest heterogeneity and seral-stage variation, which are important for owl habitat resiliency and foraging; 2) an overall densification of forests due to a century of fire suppression, which puts owl habitat at risk of loss due to fire, insects, disease, and drought; 3) a deficiency in very large, old trees (and associated snags and downed logs), which are important components of owl nesting, roosting, and foraging habitat; 4) a reduction in shade-intolerant and fire-resistant tree species, which are important components of fire-resilient forests; 5) some deficiency in the cover or diversity of understory forbs and shrubs at localized scales coupled with a surplus of understory litter and woody debris, which detracts from owl prey habitat and increases the risk of habitat loss to fire; and, 6) a disrupted fire regime that includes too little low- and moderate-severity fire and too much high-severity fire, which adversely affects vegetation structure, composition, and function, and which destroys large blocks of important owl habitat.

One primary component of California spotted owl conservation is to restore Sierra Nevada forests to, or at least toward, the natural range of variation. Restored forests provide two essential benefits to the species. First, restored forests include the range of conditions in which the species evolved and persisted prior to European settlement, thereby providing the species the full complement of habitat it needs to carry out all its essential life functions. Second, restored forests are more heterogeneous and resistant and resilient to many disturbances, such as fire, insects, disease, drought, and climate change, thereby reducing the risk of losing essential California spotted owl habitat in the future.

To inform the development of habitat conservation measures, this section describes the historic condition and natural range of variation for California spotted owl habitat in the Sierra Nevada region, recent changes to this habitat and the factors contributing to these changes, future expected changes, and the environmental context and drivers shaping these ecological systems. This information is summarized from much more in-depth syntheses, including Safford and Stevens 2017.

Environmental Context

Mid-elevation Sierra Nevada forests are highly productive and have some of the highest biomass values for temperate forests worldwide. The tree species are long-lived, with tall, complex canopy structures that significantly influence site microclimate and habitat condition. Sierra Nevada forests are also fire-dependent ecosystems. Historically, these ecosystems burned frequently (generally less than 20 years), and the fires were low to moderate severity. Because the fires were generally surface fires with localized high-severity patches, they reduced tree densities and moisture stress related to tree competition in these drier environments while increasing spatial, habitat, and microclimate diversity. Early surveys noted fire produced variable but generally low-density forest conditions (Lieberg 1902). Lieberg (1902) noted Sierra Nevada forests were at only 30 percent of their carrying capacity for timber production. Over the last few decades, research has demonstrated that more resilient forests have lower density and more open conditions than the traditional concept of full stocking for maximum timber production (Collins et al. 2011 and 2015, Stephens et al. 2015).

Sierra Nevada forests combine drier and moister conditions into one, highly variable ecosystem. Overstory forest conditions are shaped by the number, size, and composition of large, long-lived trees like those in Pacific Northwest forests. These conditions are influenced by local levels of productivity. In particular, areas with higher soil moisture support more large live and dead trees, denser canopy cover, and greater biomass. Understory conditions, are strongly influenced by the local fire regime like those in the Southwest forests. Tree regeneration, stand density, shrub cover, and microclimate conditions are affected by the frequency, intensity, and spatial extent of burn patterns (Knapp et al. 2013, Collins et al. 2015). Because fire is a frequent process shaping the system in the Sierra Nevada, old forests there generally have space between different canopy layers (Stephens and Gill 2005), which reduces crown fire potential. This is very different from old-growth forests, such as those in the Pacific Northwest, which often have dense, overlapping, multi-layer canopies. The condition of the Sierra Nevada ecosystem cannot be assessed by the abundance and size of forest structures alone but needs to consider fire history including severity, frequency, and patch structure (Collins and Stephens 2010).

Forest stand conditions and forest landscape patterns in the Sierra Nevada appear to be generally influenced by local rates of actual evapotranspiration and climatic water deficit. Actual evapotranspiration is a measure of how much water actually transpired and indicates potential tree growth and size. Climatic water deficit is a measure of the difference between potential and actual evapotranspiration and is an indirect measure of a site’s moisture stress on vegetation (that is, how dry a site is). Actual evapotranspiration and climatic water deficit, together, effectively estimate the water balance for a given site; that is, water loss due to transpiration relative to water and energy (temperature, solar insolation) inputs. Together these metrics can serve as a proxy of site productivity for a given area, and consequently potential species composition, tree growth, and tree size (Lutz et al. 2010). Actual evapotranspiration has been significantly correlated with many habitat attributes important for the California spotted owl, including the abundance of large live trees, snags, and large logs; canopy cover; and biomass. Climatic water deficit has been generally correlated with fuel moisture conditions and, in some instances, susceptibility to bark beetle attack. Therefore, it is indirectly correlated with local fire regimes. Local fire regimes most directly influence understory conditions such as shrub cover and composition, small tree density, and the litter and bare ground conditions that influence germination success of different species. Due to these correlations, actual evapotranspiration and climatic water deficit may be strong predictors of historic forest condition associated with large trees, as well as conditions that will be more resilient in the future (Stephenson 1998). Areas of low productivity, unlikely to support

nesting and roosting habitat for California spotted owls, can be generally identified through their association with low actual evapotranspiration and/or high climatic water deficit. Locations of frequent fires may be roughly associated with high climatic water deficit, but physiographic characteristics (slope position, aspect, steepness, etc.) may be a more direct measure of factors that affect fire occurrence and intensity. However, historic forest conditions were also influenced by other factors such as tree-killing insects such as bark beetles (Fettig 2015), disease, and wind-throw, as well as the spatial and temporal variability inherent in disturbance events.

Current Conditions Relative to Historic Conditions

Driving Forces

The subsections below describe changes to the California spotted owl habitat in the Sierra Nevada over the last century that influence both owl habitat use and selection today, as well as resilience of owl habitat to future disturbance. In general, the two strongest management influences on current forest conditions in the Sierra Nevada are historic logging and fire suppression over the last 100 or more years. Prior to the 1990s, logging in the Sierra Nevada often removed the largest trees and selected pines over fir and cedar (Laudenslayer and Darr 1990, Stephens 2000). Forest management also removed ‘defect’ trees – those with broken tops, multiple leaders, mistletoe infections, etc. These trees had characteristics associated with preferred habitat for species such as the California spotted owl. In general, historic logging and forest management reduced spatial diversity and removed large trees, snags and logs, and defect trees associated with old-forest conditions important for the California spotted owl.

Beginning in the early 1900s, fire suppression policy and practice lead to the extinguishing of nearly all fires on public lands through the late 20th century. While science has shown the detrimental ecological effects of such full suppression in fire-dependent ecosystems, concerns for human safety, protection of ecosystem services, and the heavy fuel loads created by fire exclusion have made it difficult to revise these policies in many places. The effects of fire suppression have been influenced by the highly productive conditions of the Sierra Nevada. Small trees rapidly filled in the understory and, with enough time (more than 40 years), grew to intermediate and then co-dominant size in many stands (Parsons and Debenedetti 1979). This often eliminated the diverse pattern of individual trees, clumps of trees, and openings and increased canopy cover. It also reduced species diversity as the number of fire-sensitive, shade-tolerant trees increased; reduced the variability in tree size and canopy position; and reduced variability in microclimate and habitat conditions in the understory. These reductions in habitat and species diversity likely negatively influenced species like the California spotted owl and their prey.

McKelvey and Johnston (1992) highlight four key changes in forests since 1850: 1) loss of old, large-diameter trees and associated large downed logs; 2) shift in species composition towards shade-tolerant; 3) increase in fuel associated with mortality of smaller trees; and 4) presence of ladder fuels that facilitate crown fire.

Similarly, Franklin and Johnson (2012) outline four significant changes seen in fire-prone or dry mixed-conifer forests over the last century: 1) fewer old trees of fire-resistant species, 2) denser forests with multiple canopy layers, 3) more densely forested landscapes with continuous high fuel levels, and consequently, 4) more stands and landscapes highly susceptible to stand-replacement wildfire and insect epidemics.

In addition to decreasing key habitat elements for the California spotted owl, these changes also generally make current forests less resilient to two of the most common disturbances in the Sierra

Nevada: fire and drought. High fuel loads and connectivity of ladder fuels and tree crowns increase the likelihood of high-intensity crown fire occurrence and extent (Agee and Skinner 2005, Stephens et al. 2009). Stands without gaps in areas with low soil-moisture-holding capacity (for example, shallow soils) are highly susceptible to drought stress. This stress, in turn, increases the likelihood of tree mortality from insects and disease, particularly from bark beetles (Kolb et al. 2015). This decrease in habitat resilience increases the likelihood of loss of California spotted owl habitat to disturbance in the future. This decrease in resilience is likely most significant in locations where low productivity, frequent fires, or both, historically kept forests generally at a low density and with a higher percentage of drought- and fire-resistant pines. In other words, the key spotted owl nesting and roosting habitat that may be most at risk, exists in locations where it may not have occurred under a natural disturbance regime.

Below, changes in forest structure and composition, particularly those key to the conservation of the California spotted owl, and essential disturbance processes are described. A summary of information on California spotted owl populations relative to past conditions is also included.

Climate

Over the last 7,000 to 8,000 years, dry climate periods have occurred on average every 80 to 260 years, with droughts lasting 20 to 100 years on many occasions (Safford and Stevens in review). The Sierra Nevada has been anomalously wet in 19th and 20th centuries and anomalously cool in the 19th century (Haston and Michaelsen 1997, Hughes and Brown 1992, Safford and Stevens 2015). However, several recent assessments report the world's forests are increasingly vulnerable to ongoing warming and drying due to climate change (Allen et al. 2010, Martinez-Vilalta et al. 2012, Fettig et al. 2013, Vose et al. 2016). The reports suggest the effects of a warming, drying climate on tree mortality range from modest and short-lived local increases to acute, regional-scale episodes often involving large-scale insect outbreaks. While these episodes are well-documented, the underlying causes of tree mortality are complex and likely involve numerous factors. Nevertheless, recent and future increases in tree mortality in the Sierra Nevada and elsewhere in the western United States have been closely linked with increased moisture stress associated with a warming climate (van Mantgem et al. 2009, van Mantgem and Stephenson 2007), which exacerbate the impacts of interactive stressors on forest ecosystems (Millar and Stephenson 2015). Changes to forest structure, composition, and function over the last century have placed Sierra Nevada forests, and particularly larger and older trees on which many wildlife (for example, the California spotted owl) depend, at high risk for drought stress and mortality (McDowell and Allen 2015, van Mantgem et al. 2013).

Forest Conditions

Tree Densities and Sizes

Studies suggest that tree sizes have generally declined over the last century, reducing the availability of large trees preferred by California spotted owls. Additionally, tree densities, particularly densities of small trees, have increased. These changes have decreased the resilience of owl habitat and increased competition among trees that owls rely on.

Reconstructed tree densities from pre-settlement conditions range from 24 to 132 trees per acre (60 to 328 trees per hectare) of trees greater than 4 inches in diameter at breast height; the average is 64 trees per acre (159 trees per hectare) (Safford and Stevens 2015, Taylor 2004, Scholl and Taylor 2010, Collins et al. 2011, 2015, Stephens et al. 2015). Contemporary mean tree density is 160 trees per acre (397 trees per hectare), with densities ranging from 96 to 306 trees per acre

(238 to 755 trees per hectare) in the same stands for which presettlement reconstructions exist. Increases in forest density range from 80 percent to 600 percent, with most of this increase in trees less than 24 inches (60 centimeters) in diameter at breast height (Safford and Stevens 2017).

Average and maximum tree sizes in Sierra Nevada forests are smaller than in the past (Collins et al. 2017). Historically, the yellow pine and mixed-conifer forest types were characterized by higher densities of large trees and lower densities of small trees (Dolanc et al. 2014). Compared to historic forests, the average tree size has declined 60 percent and 26 percent in the Tahoe Basin and Stanislaus National Forests, respectively (Taylor et al. 2014, Lydersen et al. 2013). Trees greater than 36 inches in diameter at breast height have declined in abundance, trees 24 to 36 inches have decreased in some places and increased in others, and trees less than 24 inches in diameter at breast height have increased (Verner et al. 1992, North et al. 2007, Fellows and Goulden 2008, Lutz et al. 2009, Scholl and Taylor 2011, Dolanc et al. 2014, McIntyre et al. 2015, Stephens et al. 2015; Collins et al. 2017). Historic pine and mixed-conifer forests likely contained an average of about 4 to 16 trees per acre larger than 24 inches in diameter at breast height and an average of 1.5 to 8 trees per acre larger than 36 inches in diameter at breast height (averaged at the landscape scale; Collins et al. 2015; Stephens et al. 2015).

While timber harvest and tree planting explain some of the shift from larger to smaller trees, similar patterns also occur in unlogged forests, suggesting other factors are at play. These might include insects, pathogens, and drought stress, which are likely exacerbated by the higher stand densities in modern forests (Safford and Stevens 2015).Tree mortality rates during recent drought have been shown to be positively correlated with increased tree density (Young et al. 2017).

Table 1. Description of tree diameters (in inches at breast height) used as benchmarks in this Strategy

Tree Diameter	Reason for Interest
24 inches	‘Large tree’ lower natural range of variation indicator
30 inches	General benchmark for retention, based on owl habitat selection (90 percent of recorded conifer nest trees are this size or larger)
35 inches	General benchmark of importance for owl nest tree selection (75 percent of recorded conifer nest trees are this size or larger)
36 inches	‘Very large tree’, benchmark at which current deficit (particularly in pine species) becomes fairly universal
40 inches	Upper benchmark for exceptions to retention recommendations due to current abundance relative to historic abundance, though shade tolerant species of this size may be more abundant today than historically, (approximately 70 percent of recorded conifer nest trees are this size or larger)

Snag density has increased in Sierra Nevada forests (Safford and Stevens 2017); however, the snags are significantly smaller than in the past (Knapp 2015). Current snag densities average about 8 to 20 snags per acre (20 to 50 snags per hectare); snag size is 6 inches (more than 15 centimeters) in diameter at breast height (Safford and Stevens 2017, Stephens et al. 2007, Youngblood et al. 2004, Dunbar-Irwin and Safford 2016). While an increase in snags may benefit California spotted owls, they prefer large and very large snags, which may be declining.

Historic average densities likely ranged from 1.6 to 5 snags per acre (4 to 12 snags per hectare) (Stephens 2004, Stephens et al. 2007, Dunbar-Irwin and Safford 2016). Agee (2002) suggested forest types with frequent fire regimes should support around 2 snags per acre (5 snags per

hectare), with the average snag size of approximately 30 inches (75 centimeters) in diameter at breast height.

Canopy Cover

Canopy cover is another habitat attribute considered important for the California spotted owl. Average canopy cover for historical pine and mixed-conifer forests has been estimated between 17 percent and 49 percent, with many studies reporting canopy cover below 35 percent (Safford and Stevens 2015, Collins et al. 2011, Lydersen and North 2012, Collins et al. 2015, Stephens et al. 2015). Models predict that most of the landscape was historically in open conditions (defined as less than 50 percent canopy cover for mixed-conifer and less than 40 percent canopy cover for yellow pine forests), especially in the yellow pine and dry mixed-conifer types (Safford and Stevens 2017). These models also predict that dense, older stands occupied around 5 percent of the landscape in the yellow pine and dry mixed-conifer types and around 20 percent of the moist mixed-conifer type (Safford and Stevens 2017). Overall, pre-settlement fire regimes likely supported approximately 12 percent of the yellow pine mixed conifer forest in closed canopy conditions (Miller and Safford 2017). Forest inventory and analysis data suggest a current average canopy cover around 46 percent, although this is likely an underestimation (Fiala et al. 2006). Current conditions represent an increase in average canopy cover of around 25 percent (Safford and Stevens 2015) to an average of about 46 percent to 50 percent (Safford and Stevens 2017; Stephens et al. 2015). This increase in canopy cover may have benefited spotted owls in some locations by creating potential nest/roost habitat where it would not have existed historically (for example, in more xeric conditions), but also has likely negatively impacted the owls by increasing the area of the high cover, small-to-medium tree habitat they tend to select against (North et al. 2017).

Table 2. Description of canopy cover categories used as benchmarks in this Strategy

Canopy Cover	Reason for Interest
0-40(50%)	‘Low’ or ‘open’ canopy cover for spotted owl habitat (vegetation/ecosystem)
40-70%	‘Moderate’ or ‘medium’ canopy cover (defined by remote sensing derived products such as GNN or EVEG) for spotted owl habitat, from owl scientific literature
50-100%	‘Closed’ canopy for vegetation/ecosystem conditions, from natural range of variation information and LANDFIRE Biophysical Settings (BpS) model
70-100%	‘High’ canopy cover (defined by remote sensing derived products such as GNN or EVEG) for spotted owl habitat, from owl scientific literature
Multi-storied canopy	Overlapping canopy cover with representation in multiple vegetation strata

Tree Species Composition

Forest composition has shifted from historic conditions, with declines in abundance of shade-intolerant pines and increases in shade-tolerant species like firs and cedars (Barbour et al. 2002, Guarin and Taylor 2005, Dolanc et al. 2014, McIntyre et al. 2015, Stephens et al. 2015). Reduced understory light and thick litter layers (due to increases in canopy cover and decreases in fire frequency) favor regeneration of fire-sensitive, shade-tolerant species, which decrease fire resilience of Sierra Nevada forests. Relative proportions of shade-intolerant to shade-tolerant species changed from 60:40 to 35:55 between 1930s and 2000s, with the stand component of

shade-intolerant species like yellow pines dropping from about 2/3 to about 1/3 of the mature forests over the last century (Safford and Stevens 2017).

In some areas, pine forests have been replaced by mixed-conifer forests. Dolanc and others (2014), found 19.7 percent of 1930s plots were classified as ponderosa pine versus 8.9 percent of the plots from the 2000s. Twenty-seven point four percent of plots were classified as mixed conifer in the 1930s dataset versus 37.1 percent in the 2000s, with similar reductions in Jeffrey pine. Current Forest Service vegetation maps show 17 percent of the region in yellow pine and 30 percent in mixed-conifer forests, compared to 33.7 percent in yellow pine and 19.8 percent in mixed conifer in Show's and Kotok's (1929) summary of 1920s conditions (Safford and Stevens 2017). The broad mixed-conifer category represents a diverse array of conditions, as it includes pine-dominated, mixed-conifer forests (Collins et al. 2011 and 2015, Stephens et al. 2015) and fir-dominated, mixed-conifer forests (Stephens and Collins unpublished data). The pine-dominated, mixed-conifer forests had lower tree densities and canopy cover and were dominated by shade-intolerant species versus the fir-dominated areas with higher densities and basal area.

Tree Mortality

Recent studies have documented high mortality rates of trees throughout the Sierra Nevada (van Mantgem et al. 2009), including higher-than-expected, accelerating losses of trees more than 36 inches in diameter at breast height (Smith et al. 2005, Lutz et al. 2009, Fellows and Goulden 2012, McIntyre et al. 2015). This suggests that key habitat elements for California spotted owls are at high and increasing risk of loss due to mortality.

Historically, mortality was primarily driven by fire, which burned smaller tree sizes and fire-sensitive species. Small trees only survived and grew large enough to escape being burned because fire frequency and extent were random (Stephens et al. 2008). Some areas were missed by fire; other microsites were less likely to burn due to wetter conditions or fuel barriers like streams and rocks. In general, this produced forests with a low density of large trees, because, while few individuals escaped the cycle of fire-driven mortality, those that did may have thrived in conditions with reduced water and light competition, producing large, long-lived, more fire-resilient trees.

The increasing mortality of large trees today is attributed to climate change, drought, and water stress (Fellows and Goulden 2008, Lutz et al. 2009, McIntyre et al. 2015) interacting with multiple other factors, including pathogens, insects, and air pollution (Guarin and Taylor 2005, Smith et al. 2005, Das et al. 2011, McIntyre et al. 2015). The few data available on tree mortality rates suggest background (continuous, low level) mortality rates today are higher than in the past. Background mortality rates (averaged over multiple years) in the Sierra Nevada forests are between about 0.25 percent and 1.4 percent for fire-excluded forests but less than 0.5 percent for forests with largely intact fire regimes (In Safford and Stevens 2015: Ansley and Battles 1998, Maloney and Rizzo 2002, Stephens and Gill 2005).

In recent decades, particularly since 2012, there has been a dramatic increase in loss of large trees due to bark beetles, which are currently considered one of the principal agents of tree mortality in the Sierra Nevada (Fettig 2012, 2015). Most notable in the range of the California spotted owl are the western pine beetle, mountain pine beetle, Jeffrey pine beetle, pine engraver beetle, and fir engraver beetle. Depending on the bark beetle species and numerous other factors (Fettig et al. 2007), the extent of tree mortality may be limited to small groups of trees or impact extensive areas. Outbreaks occur when favorable forest and climatic conditions coincide, and climate change is likely exacerbating bark beetle impacts (Bentz et al. 2010). Warming temperatures have

triggered population increases in many insect species which have resulted in widespread outbreaks (Millar and Stephenson 2015).

Current examples of these widespread outbreaks and associated tree mortality are evident in the low- to mid-elevation coniferous forests of the southern Sierra Nevada, where western pine beetle has had a widespread impact on ponderosa and sugar pines (USDA 2017b). The combination of dense forest conditions and forest canopy water loss due to drought has caused rapid (1 to 2 years) and extensive tree mortality (Asner et al. 2015, Young et al. 2017). Between 2009 and 2014 (pre-drought and early drought), the median predicted amount of mortality for a stand of intermediate basal area was less than 0.1 tree per acre (25 trees per square kilometer). It rose to 1.4 dead trees per acre (345 dead trees per square kilometer) in 2015 (Young et al. 2017). Further, drought conditions caused higher mortality in dense stands than in stands with low basal area (Young et al. 2017).

Bark beetle infestations are influenced by factors such as overall stand density, tree diameter, tree vigor, and host species density. Currently, slower-growing ponderosa pines (which are more fire tolerant) are more susceptible to attacks (Craighead 1925, Miller 1926). Various measures of stand density, including stand density index or the total basal area of all trees in a stand, are positively correlated with levels of tree mortality from bark beetles (Hayes et al. 2009). Host density had less predictive power than other measures of stand density, suggesting tree density and, indirectly, competition are more important (Hayes et al. 2009). It is well documented that there are increased competition for resources (especially water and light) and reduced tree vigor in higher density stands. This makes individual trees less resistant to bark beetle attack (Fettig et al. 2007, Safford and Stevens 2017). For example, when soil moisture is limited, trees close the tiny openings in their needles and leaves to avoid excessive water loss. This leads to reduced productivity because closure also prohibits uptake of carbon dioxide and, ultimately, photosynthesis. Reduced productively directly compromises a tree’s pest resistance.

Reducing tree density reduces competition and helps maintain productivity. This increases insect and disease resistance mechanisms and decreases the susceptibility of individual trees, stands, and forests to bark beetle infestations (Fettig et al. 2007). Stand density index is a commonly used measurement in forest management to describe the relationship between tree size and number and risk of mortality. In northern California ponderosa pine stands, a stand density index value of 230 is the threshold for mortality from bark beetles; the maximum stand density index is 365 (Oliver 1995, Hayes et al. 2009). As maximum stand density index varies by species, mixed species stands have different recommended stand density index values. For even aged, Sierra Nevada mixed conifer stands, an upper stand density index value of 250 is recommended in stands with higher composition of pine and 300 in stands with higher composition of fir to avoiding substantial self-thinning mortality based on a corresponding maximum stand densities of 450 and 550 (Long and Shaw 2012). Hayes and others (2009) suggest it might be appropriate to consider lower stand density index thresholds under some conditions; for example, during elevated bark beetle populations associated with extended droughts in California.

Variability across Spatial Scales

Variability in forest structure and composition is becoming increasing recognized as a salient feature of reference forests. This variability is a product of both an intact disturbance regime (mainly fire, but insects and disease as well) and underlying growing conditions (also thought of as site productivity). Fire is inherently variable, even independent of vegetation and fuel conditions, due to the strong influence of weather and topography on fire behavior. Similarly, site productivity can vary considerably owing to differences in soil properties, climate, and

topography. Despite this understanding of the primary processes influencing variability in forest conditions, there is quite a bit of uncertainty in characterizing variability across different spatial scales. The following sub-sections offer some guidance as to how variability in forest structure and composition may have been organized across spatial scales under the natural range of variation.

EcoRegion

The Sierra Nevada Ecoregion makes up the majority of the California spotted owl range, though the owls also occur in southern and central coastal California. The Sierra Nevada Ecoregion supports a diversity of habitat zones, influenced by climate, topography, elevation, longitude, and latitude. The key habitat zones for the California spotted owl include, most importantly, the mixed conifer and yellow pine forests (80 to 90 perfect of known owl habitat), followed by the red fir and red fir-lodgepole pine forests (approximate 10 percent of known habitat), and the riparian and hardwood forests (approximately 3 percent of known habitat; Verner 1992). These habitat zones vary in forest structure, species composition, and fire regime, and habitat selection by owls in each of these zones will vary accordingly.

Habitat Zone

The habitat zone scale, greater than 100,000 acres in size, represents the broad yellow-pine mixed-conifer forest zone of the Sierra Nevada ecoregion, for which much of the natural range of variation information has been summarized collectively (that is, Safford and Stevens 2017). The habitat zone scale roughly corresponds to the geographic range of the California spotted owl in this ecoregion (about 90 percent of the range). This zone includes several distinct compositional (and structural) forest types. One readily used vegetation classification for distinguishing among such forest types within the Sierra Nevada region is the LANDFIRE biophysical settings. LANDFIRE biophysical settings represents modeled potential vegetation types under an intact fire regime. As indicated by its name the modeled types are based on several biophysical or environmental parameters (elevation, aspect, soils, climate), but what differentiates biophysical settings from other potential vegetation classifications is that it incorporates the influence of an intact disturbance regime on species composition and structure. Safford and Stevens (2017) determined that biophysical settings models 610270 (Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland), 610280 (Mediterranean California Mesic Mixed Conifer Forest and Woodland), and 610310 (California Montane Jeffrey Pine-Ponderosa Pine Woodland) best represented dry mixed conifer, moist mixed conifer, and yellow pine, respectively.

These three biophysical settings forest types (yellow pine, dry mixed conifer, and moist mixed conifer) likely capture a coarse-scale gradient in site productivity within the broader yellow-pine mixed-conifer forest region. This productivity gradient would be expected to correspond with changes in tree density and species composition, even under an intact fire regime (for example, Collins et al. 2015, Stephens et al. 2015). That said, due to the relatively recent nature of biophysical settings and limited geographic availability of both historical forest reconstructions and contemporary reference sites, the scientific literature is lacking robust distinctions of the natural range of variation among these forest types. Despite not having distinct quantitative metrics for each of these forest types there is a reasonable scientific basis for inferring that each of these forest type is captured within the ranges in tree densities, basal area, species composition, and canopy cover presented in the preceding sub-sections. As a general rule the natural range of variation for the yellow pine type would likely be towards the lower end for tree density, basal area, shade-tolerant species composition, and canopy cover, while the moist mixed conifer type

would be towards the upper end of these ranges. Dry mixed conifer would likely be in between these two types.

Landscape

The landscape scale, roughly 10,000 to 100,000 acres in size, generally corresponds to the scale of a few to tens of spotted owl home ranges. Forested landscapes historically associated with frequent fire have changed considerably as a result of fire suppression, fire exclusion, and past land management practices (Gruell 2001, Hessburg et al. 2005). This change is characterized by the transition from an array of distinct successional patches (or stands) distributed throughout a landscape towards a comparatively uniform condition of moderate- to dense tree cover with similar stand/age structure (Hessburg et al. 2015) . Topography has been identified as a driver of forest structure and composition in areas with intact fire regimes (Taylor and Skinner 2003, Beaty and Taylor 2008, North et al. 2009, Lydersen and North 2012). In landscapes in which fire has been excluded for a long time, this topographic signal is substantially muted or absent (Lydersen and Collins, in review). The specific topographic characteristics—slope aspect, elevation, and slope position—primarily influence solar insolation, precipitation, and temperature across a landscape. These processes interact with soil properties to ultimately affect energy and water availability, which are captured by the previously mentioned actual evapotranspiration and climatic water deficit (Stephenson 1998). In the Sierra Nevada, sites with both higher actual evapotranspiration and climatic water deficit tend to favor more pine-dominated forests, while those with lower actual evapotranspiration and climatic water deficit favor fir-dominated forests (Lutz et al. 2010). These two measures (part of the “biophysical environment”) have been shown to explain variability in forest structure and composition across landscapes with intact fire regimes (Collins et al. 2015, Kane et al. 2015, Stephens et al. 2015, Collins et al. 2016). As with the use of broad forest types to subset the ranges in the natural range of variation of forest structure and composition at the regional scale, there is a strong a scientific basis for using actual evapotranspiration and climatic water deficit to vary natural range of variation targets at the landscape scale. It is difficult to put absolute ranges on actual evapotranspiration and climatic water deficit due the potential differences in sources and resolutions of the input data (that is, climate and soils), as well as in approaches for calculating them. As such, actual evapotranspiration and climatic water deficit are probably most useful as relative measures within a given landscape. Regardless, these metrics may be useful for identifying areas where the biophysical environment is likely to support different forest structures. For example, areas with higher actual evapotranspiration, in combination with relatively low climatic water deficit, are more likely to support higher densities of large trees, which has been shown to be an important component of California spotted owl habitat (North et al. 2017).

Patch Neighborhood

The patch neighborhood scale, approximately 1,000 to 10,000 acres in size, roughly corresponds to the scale of a spotted owl territory home range. Forest-dominated landscapes comprise many vegetation patches, or stands (Hessburg et al. 2015). These patches are distinct from one-another in terms of vegetation type (for example, tree or shrub dominated), forest structure and species composition, disturbance history, or a combination of those things. The patch neighborhood scale connects the stand or patch scale (10 to 1,000 acres) to the landscape scale (10,000 to 100,000 acres) and is highly relevant to disturbance spread patterns, distribution and habitat use patterns of species with large home ranges, and forest management planning. As the name suggests, a patch neighborhood is made of adjacent vegetation patches, perhaps up to 10 individual patches. While there may be distinct patches within a neighborhood, there is some feature (like landform) that connects them. A subwatershed is a prime example of a patch neighborhood, in which

conditions and events in one patch strongly influence the surrounding patches. Within a patch neighborhood, slope aspect and slope position will strongly influence the vegetation type and forest structure and composition. Beaty and Taylor (2008) studied historical forest structure and composition within a subwatershed in the Lake Tahoe Basin and demonstrated that more even-aged, fir-dominated stands and montane chaparral patches existed on north-facing aspects and in upper slope positions. These patterns have also been demonstrated in the Klamath Mountains (Taylor and Skinner 1998) and in the southern Cascade Range (Beaty and Taylor 2001). Mid-slope positions would be expected to have more open, multi-aged stands, dominated by pine. Valley bottoms would also be expected to have multiple age classes, but might support overall higher densities than mid-slope positions due to greater water availability. Variability at this scale is critical for species like the California spotted owl to meet all of their life requisites, and both influences and is influenced by natural disturbance and microclimate patterns. Patch neighborhoods that contain a mosaic of patches burned at lower severities in different years, interspersed with large unburned patches and small high-severity burned patches, can provide both the habitat diversity and edges that benefit owls (Eyes et al. 2017) and their prey (Roberts et al. 2015).

Stand or Patch

The stand (or patch) scale, tens to 1,000 acres in size, roughly corresponds to the scale of a spotted owl nest site, up to a spotted owl protected activity center or territory. A defining characteristic of historic Sierra Nevada forests at this scale was heterogeneity in tree spatial distribution, density, and species composition (North et al. 2009, Collins et al. 2015). Recent studies have quantified the distributional heterogeneity of frequent-fire forests as characterized by a pattern of individual trees, clumps of trees, and openings (Larson and Churchill 2012, Fry et al. 2014). The proportion of area in each of these conditions, the tree density and basal area, and opening size and location likely varied with local differences in productivity, topography, localized fire behavior, as well as the overall fire regime. Drier conditions associated with upper slope, ridge top, and southwest aspects likely had smaller tree-clumps, larger openings, lower basal area and density, and a higher percentage of pine species. In contrast, more mesic locations, such as lower slope and valley bottom sites, more often supported large tree clumps, higher canopy closure, smaller openings, and a higher percentage of fire-sensitive, shade-tolerant species such as fir and cedar.

This heterogeneous spatial pattern at the stand scale has been linked to forest resistance and resilience to disturbance (Show and Kotok 1924, Stephens et al. 2008, Fry et al. 2014) and also increased habitat diversity for wildlife like the California spotted owl. For example, gaps in forests dominated by individual trees, clumps of trees, and openings under moderate fire weather may limit the spatial extent of high-intensity crown fires and high-severity patches (Kennedy and Johnson 2014). Spatial variability in forest structure may also have made forests more resilient to drought because clumped trees had adjacent openings and areas of low tree density that reduced moisture competition, thereby potentially reducing tree susceptibility to mortality from bark beetles (Fettig 2012). Likewise the extent and severity of some pathogen and pest damage can be limited by variability in tree species and spatial composition because some pests and pathogens are host-specific and influenced by overall stand density.

Forest stands at fine (stand and sub-stand) scales are more homogeneous today than historically, with less patchy patterns of tree size and density (Agee 1993, Barbour et al. 1993, 2007; SNEP 1996, Sugihara et al. 2006), increased tree clump size (for example, more trees per clump; Lydersen et al. 2013), and decreased proportion in canopy gaps (Lydersen et al. 2013). The density of gaps has decreased from an average around 5 to 6 gaps per hectare(approximately 2 to

2.5 gaps per acre) to less than 0.1 gap per acre on average (Lydersen et al. 2013), and the average gap size has decreased dramatically. Forest structure has also been 'simplified', including declines in large trees, snags, woody debris of large diameter, canopies of multiple heights and closures, and complex spatial mosaics of vegetation (SNEP 1996, Safford and Stevens 2017). These stand and landscape-level reductions in structural and patch heterogeneity have likely dramatically decreased forest resistance and resilience to disturbance as well as habitat variability for owl prey species.

Fire and Ecological Function

Fire Regime

Fire is a key ecological process in the Sierra Nevada region, historically shaping the vegetation communities and the wildlife populations they supported. Fire has changed significantly over the last century due to fire suppression and changing climatic conditions. Yellow pine and mixed-conifer forests historically supported fire regimes with frequent, low- to moderate-severity fires (from Safford and Stevens 2015: Agee 1993, Arno 2000, Barbour et al. 2007, Barbour et al. 1993, Skinner and Taylor 2006, van Wagtendonk and Fites-Kaufman 2006).

Fire frequency is measured as a fire return interval which is the average number of years between two successive fires (Agee 1993). Before extensive fire suppression, mean fire return intervals for yellow pine and mixed-conifer forests across California ranged from 11 to 16 years (Stephens et al. 2007, Van de Water and Safford 2011, Safford and Stevens 2015). Fire frequencies were highest in the drier, lower-elevation forest types (yellow pine and dry mixed-conifer) and lower in wetter and higher-elevation stands (in Safford and Stevens 2015: Caprio and Swetnam 1995, Fites-Kaufman et al. 2007, Gill and Taylor 2009, Sugihara et al. 2006, Taylor 2000).

Today, most pine and conifer forests in the central and northern portions of Sierra Nevada Range are more than 85 percent departed from historic fire return intervals; there have been no fires or one fire in the last century (Safford and Van de Water 2014). Most pine and conifer forests in the eastern and southern portion of the region are at least 67 percent departed from historic fire return intervals, with three or fewer fires over the last century (Safford and Van de Water 2014).

Fire rotation is the length of time necessary for an equal-sized area to reburn (Agee 1993). For the pine and conifer forests of the Sierra Nevada, the historic fire rotation ranged from 22 to 31 years (Mallek et al. 2013). Fire rotations are about 10 times longer than they were historically on National Forest System lands and about twice as long in Yosemite National Park (Miller et al. 2012, Safford and Stevens 2017). Current fire rotation on Forest Service managed pine and conifer forests averages 258 to 280 years, with a range of 95 to 516 years (Miller et al. 2012), and about 55 years in Yosemite National Park.

North and others (2012) estimated that, under a historic fire regime, an average of 183,778 to 487,846 acres would have burned annually on National Forest System land in the Sierra Nevada region. The authors also estimated the current rate of burning (including both prescribed and wildfire) on National Forest System lands is only about 59,325 acres annually (North et al. 2012). When the area of mechanical treatment is added, the total acres of fire or fire-mimicking activity averaged 87,923 acres per year (North et al. 2012). These annual fire and treatment rates are less than the lowest possible historical figures and have led to an estimated 2.9 million acres of 'backlogged' forest in need of fire, treatment, or both. These acres have seen increases in snag density, coarse woody debris, litter and duff depth, and surface fuel volume and continuity

(Safford and Stevens 2015). This likely represents a decrease in habitat heterogeneity and resilience for the California spotted owl over much of its range.

Fire Severity

Historically, the amount of forest burned at high severity was likely a very small proportion of the total area burned. Mallek and others (2013) and Miller and Safford (2017) indicate that historically only 5 to 10 percent of any burn at any given time would have been high severity. Safford and Stevens (2017) describe average percentages of high severity by major vegetation types, which they note correspond with Landfire biophysical settings types, with yellow pine at 5.9 percent, dry mixed conifer at 7.1 percent, and moist mixed conifer, 11.6 percent. Stephens and others (2015) suggest an even lower proportion of high-severity fire in the southern Sierra Nevada: 1 to 3 percent in mixed-conifer and 4 to 6 percent in ponderosa pine forests. These high-severity areas were likely aggregated in small patches (usually less than 5 acres) distributed across the landscape (Show and Kotok 1924, Collins and Stephens 2010; North et al. 2017). Given that California spotted owls use mixed-severity fire areas dominated by low and moderate severity, and generally avoid larger areas of high severity, the historic fire regime was likely beneficial to the species (Roberts et al. 2011; Lee et al. 2012, 2013; Jones et al. 2016; Eyes et al. 2017; Rockweit et al., in press). Historical fire regimes, with roughly 5 to 10 percent high severity per fire, would have allowed for about half of all forested area to reach late succession, providing substantial suitable habitat for the California spotted owl (Miller and Safford 2017).

Areas that burned with high severity have increased in overall proportion and patch size in recent decades (Miller et al. 2009, Miller and Safford 2012, Steel et al. 2015). Both are well above historical conditions (Mallek et al. 2013, Stephens et al. 2013, Stephens et al. 2014, North et al. 2017). Average fire in modern mixed-conifer and yellow pine forests on National Forest System lands have 5 to 7 times more area of stand-replacing fire than before Euro-American settlement (29 to 35 percent high severity) (Miller et al. 2009, Miller and Safford 2012, Mallek et al. 2013, Safford 2013). Recent fires in the Sierra Nevada have included stand-replacing fire extending for thousands or even tens of thousands of acres. This is in direct contrast to stand-replacing fire in areas of the Sierra Nevada where the fire regime is intact or has been restored. In these reference landscapes, the mean stand-replacing patch size is less than 10 acres (4 hectares) and maximum patch size generally is 250 acres or less (100 hectares or less) (Collins and Stephens 2010; Miller et al. 2012; Safford 2013). Large, contiguous areas of severe fire can cause shrubs to replace conifer forest. The shrubs are then perpetuated by subsequent fires (Willken 1967, Collins and Roller 2013, Coppoletta et al. 2016). Recent studies also suggest high-severity reburns are likely in areas of initial high-severity fire (Thompson et al. 2007, van Wagtendonk et al. 2012, Lydersen et al. 2017, Harris and Taylor 2017). In the northern Sierra Nevada and southern Cascades, under specific fire weather conditions, the high densities of snags, down woody debris, and shrubs from initial high-severity burns are driving factors in high-severity reburns (Coppoletta et al. 2016), increasing risk of conversion from forest to shrub or grassland habitats unlikely to support species like the California spotted owl.

Fire Size

In comparison to early 20th century fires, current maximum fire sizes are much larger, but small fires (less than 10 acres or 4 hectares) are now more common because of the success of modern fire suppression methods. Average fire size (when including fires that are immediately suppressed) in contemporary California yellow pine and mixed-conifer forests is likely much smaller than in pre-settlement forests. For example, fires less than 10 acres accounted for 96 percent of all fires in the Sierra Nevada framework area from 1992 to 2011, but only 76 percent

of all fires that burned from 1911 to 1920 in yellow pine and mixed-conifer forests. As a result, mean fire size for the Sierra Nevada framework area during 1992 to 2011 was 60 acres (24 hectares) compared with 126 acres (51 hectares) from 1910 to 1920 (Show and Kotok 1923, Short 2013, J. Miller unpublished data).

On the contrary, average fire size when excluding those fires that are immediately suppressed, has likely increased dramatically. Average fire size in California mixed-conifer forests before Euro-American settlement has been estimated at less than 750 ac (300 hectares). The average size of fires greater than 10 acres (that is, the average of those not immediately suppressed) over the last 25 years is closer to 3,750 acres (1,500 hectares), and recent fires on National Forest System lands in California are much larger than that (Show and Kotok 1923, Taylor and Skinner 1998, Minnich et al. 2000, Taylor 2000, Beaty and Taylor 2001, Taylor and Solem 2001, Collins and Stephens 2007, Miller et al. 2012, Safford and Stevens 2015). Large fires pose an ever increasing risk to the California spotted owl (Jones et al. 2016).

California Spotted Owl Populations and designated habitat

Existing genetic data do not allow strong inference about the population history or historic abundance of California spotted owls. Additional analyses would be required to infer how current population numbers relate to historic ones. However, an analysis of the genetic variation across the range of the spotted owl showed that microsatellite variation in California spotted owls occurring in the Sierra Nevada does not seem atypical for wild populations (Funk et al. 2008). These results suggest there has been neither a severe and recent population bottleneck nor a recent population expansion from a small number of founders, either of which would have led to atypical microsatellite variations.

Shorter-term population trends are more definite. California spotted owl populations remain reasonably well distributed in the Sierra Nevada. However, in three demographic study areas on National Forest System lands, populations appear to have declined between the early 1990s and 2012 (Tempel et al. 2013, 2014b; Conner 2014). In one demographic study area, declines exceeded 50 percent during that time period, with smaller declines detected on the two other national forest demographic study areas (Tempel et al. 2014b, Conner et al. 2013). Recent work suggests recent declines may be a lag effect from past removal of large trees (and the resulting structural and compositional changes when this removal was followed by a century of fire suppression) and they are likely unrelated to recent or current habitat decline (Jones et al. 2017).

Currently, designated protected activity centers for California spotted owls cover 5 to 9 percent of productive[1] National Forest System lands in each national forest in the strategy area (North et al. 2015; unpublished data). California spotted owl territories currently encompass roughly 14 percent to 28 percent of productive lands in each national forest within the strategy area (unpublished data – note this uses 1,000 acres for all forests, so underestimates some and slightly over estimates other, also some overlap). Occupied protected activity centers and territories are well distributed across the owl's range. Trends in the number of protected activity centers is generally increasing over time, due, in part, to the ambiguity in direction regarding retiring protected activity centers and the lack of resources to survey protected activity center occupancy through time. Generally, the current amount of land allocated to protected activity centers should not likely pose a significant impediment to large-scale landscape realignment with historic conditions, more resilient conditions, or both, especially where protected activity centers align

[1] Definition of productive: Forested lands (excluding shrubs, barren, and water) with more than 10 percent canopy cover.

with biophysical conditions that will support suitable habitat in the long run. However, if the proportion of the landscape in protected activity centers increases and unoccupied protected activity centers continue to be managed as reserves indefinitely, that may pose real barriers to restoring landscape and habitat resilience in the long term. Further, watersheds where protected activity centers are particularly dense may be at elevated risk of loss due to disturbances if they are not actively restored.

Barred owl Populations

Barred owls have had profound impacts on northern spotted owl populations across large portions of the Pacific Northwest and pose one of the most significant threats to this subspecies (U.S. Fish and Wildlife Service 2011). Due to the similarities in the ecology of Northern spotted owls and California spotted owls, we expect barred owls to have similar effects on California spotted owls. Barred owls interact with spotted owls via predation, hybridization, and competition for resources. Competitive interactions appear to have the greatest impacts to spotted owls in the Pacific Northwest (Wiens et al. 2014). Significant dietary overlap exists. Both species prey on small mammals, although barred owls consume a wider variety of terrestrial and aquatic prey and prey that is active during the day (Hamer et al. 2001, Wiens et al. 2014). Barred owls also use a broader array of habitat types, but habitat overlap is considerable given similar use of young, mature, and riparian forest types. Primary differences in foraging habitat include the preferential use of older forests on steep slopes by spotted owls and the selection of flat areas near streams by barred owls (Wiens et al. 2014). Nevertheless, adjacent spotted and barred owls generally occupy distinct core areas, presumably because of competitive interactions (Wiens 2014).

The apparent competitive dominance of barred owl results in reduced spotted owl territory occupancy probabilities in the presence of barred owls (Olson et al. 2005, Crozier et al. 2006, Kroll et al. 2010, Yackulic et al. 2012 and 2014). Spotted owl reproductive success, survival, and population growth rates tends to be reduced in the presence of barred owls (Diller et al 2016).

Historically, the geographic range of barred owls (*Strix varia*) was confined to eastern North America, from southeastern Canada south to western Mexico, but this species has been expanding its range westward in North America for more than 80 years. It is not clear whether the range expansion occurred naturally or was human influenced. One hypothesis holds that the disruption of fire regimes and irrigation in the Great Plains promoted vegetation growth that facilitated westward movements (Dark et al. 1998, Gutierrez et al. 2007). Barred owls are now occurring in the same area with northern spotted owls in southern British Columbia, Washington, Oregon, and northern California (Anthony et al. 2006, Gutierrez et al. 2007).

Barred owls have recently expanded their range into the northern Sierra Nevada with a small, but increasing, number of individuals detected in the central and southern Sierra. The first barred owl detection in the Sierra Nevada occurred in Lassen County in 1989 (J. Keane, Conservation Assessment). Detections of barred and sparred (hybrid spotted and barred) owl increased from 2002 to 2013, largely because of increased spotted owl survey effort on demographic study areas in the northern Sierra.

Barred owls were first detected in the central and southern Sierra Nevada in 2004 (Seamans et al. 2004, Steger et al. 2006) and six barred owls were detected in the southern Sierra Nevada during 2011-2012 (J. Keane Conservation Assessment). The number of barred and sparred owls on the four long-term demographic study areas has remained low, although they may be increasing gradually in the northern Sierra Nevada, with eight barred and two sparred owls present on the Lassen demographic study area in 2013. As is the case generally for invasive species, the

momentum of range expansion will be far more difficult to curtail once barred owls have reached a critical, yet unknown, density. If barred owls reach such a threshold, as they have elsewhere, we can expect a rapid increase in their numbers and significant impacts to California spotted owl populations in the Sierra Nevada.

Lethal removal is the primary barred owl control strategy being considered in the range of the northern spotted owl (U.S. Fish and Wildlife Service 2011, Diller et al. 2014 and 2016, Wiens et al. 2016). Recent work indicates lethal removal of barred owls can increase spotted owl vital rates, population growth, and territory occupancy (Diller et al. 2016, Dugger et al. 2016).

Future Conditions

Climate Drivers

Climate models project increasing temperatures in California, ranging from increases of 2 to 9 degree Fahrenheit by the end of century, with the greatest increases during summer (Hayoe et al. 2004; Dettinger 2005; Hauptfeld et al. 2014). Models also suggest a larger percentage of precipitation will occur as rain rather than snow, with a 64 to 87 percent decline in snowpack. An increase in year-to-year variability in precipitation is also projected (Hauptfeld et al. 2014).

Predictions of changes in precipitation distribution and amount are highly variable, ranging from minor increases to major decreases. Because of these trends, models consistently suggest the frequency and strength of drought events will increase, likely making them a stronger influence on forest dynamics. Up to 44 percent increases in climatic water deficit are predicted, especially in the Northern Sierra Nevada (Hauptfeld et al. 2014). This change in precipitation variability and form, coupled with increasing temperatures, is why models also suggest an increase in fire frequency, size, and severity. Predictions of future forest conditions should always be viewed with caution because of large uncertainties in how complex ecosystems may respond to climatic and disturbance conditions and their interaction.

Projected Effects on California Spotted Owl Habitat and Forest Characteristics

Predictions suggest that large trees typical of old-growth forests are at greatest risk of loss in increasing periods of drought (Williams et al. 2013; Allen et al. 2015; McDowell and Allen 2015). Recent evidence shows significant drought- and density- related mortality is already occurring in southern Sierra Nevada and high levels of mortality are occurring in the larger tree size classes (USDA 2017b). This may reduce the amount of owl nesting habitat on the landscape, as well as reduce the amount of large nest trees.

Increasing temperatures and drought stress, exacerbated by high densities of suitable and susceptible host trees, greatly increase the likelihood of more bark beetle outbreaks (Raffa et al. 2008; Fettig et al. 2007, Vose et al. 2016). There is increasing long-term risk of extreme fire behavior due to increases in surface and ladder fuels which accumulate after each outbreak (Hicke et al. 2012). Forests that are less diverse are more likely to experience a broad-scale mortality event in the future (Bentz et al. 2010) and some experts suggest that reductions in existing tree density thresholds associated with highly-susceptible stands will be required to increase forest resilience to extensive pest mortality (Fettig et al. 2014). Thus, an increase in forest heterogeneity and a decrease in forest density will be critical to protecting, creating, and maintaining California spotted owl habitat in the future.

Climate projections suggest the southern Sierra Nevada may begin to see conditions similar to areas in southern California in the coming century. Thus, lessons can be gleaned from southern California mixed-conifer forests in looking towards the future. Between 2002 and 2004, a historic drought in southern California caused the widespread die-off of large-diameter conifers throughout the region (Minnich 2007). At the landscape scale, conifer mortality was highest on well-drained convex surfaces and south-facing slopes because those areas experienced greater moisture stress. Mortality was also high in dense stands, in areas that had not experienced recent fire, or both (Minnich 2007). We are seeing, and can expect to see, similar patterns in the Sierra Nevada, where larger trees, which are critical for owls, are particularly at risk (Smith et al. 2005).

If current forest conditions (high-density stands with heavy fuel loads) continue into the future, coupled with increasing disturbance frequency and severity, some general patterns are predicted. One study simulated these changes in disturbance and compared historic (low-density, pine-dominated) and current (high-density, fir-dominated) forest response. As disturbance frequency and severity increased, current forest conditions became unstable and, in a large portion of the simulations, shifted toward high density and small tree size. Historic forest conditions were much more stable, generally maintaining a low-density, large-tree, pine-dominated condition in most scenarios unless severe disturbances occurred consecutively (Earles et al. 2014).

The way forest growth models (in this case, the Forest Vegetation Simulator) simulate tree regeneration and mortality influences these predictions. High-density, fuel-loaded conditions tend to increase mortality and eventually reduce abundance of large trees and associated large snags and logs, key habitat elements for California spotted owls. Regeneration dynamics are harder to predict because disturbance timing, severity, climate, and seed dynamics all interact (Collins and Roller 2013). Generally, under more unstable conditions, species with the largest, most consistent seed production (white fir and incense cedar) tend to be favored. Millar and Stephenson (2015) found interactions from increasing temperature, drought, native insects and pathogens, and uncharacteristically severe wildfires are resulting in forest mortality beyond the levels of 20th century experience. Large areas of the southern Cascades and Sierra Nevada forests are likely to experience uncharacteristic stand-replacement fires without active fuel treatments and prescribed burn programs. The result will be loss of critical watersheds and habitat for California spotted owl and other sensitive and endangered wildlife. Substantial and repeated restoration efforts will be needed to protect them (Stephens et al. 2016a, North et al. 2012).

More surface fuels and a vegetation change from fire-resistant trees to more flammable shrubs in high-severity burned areas can constitute a significant risk to the succeeding stand (Agee and Skinner, 2005). A 2012 study by van Wagtendonk and others found high-severity burn patches were perpetuated by subsequent fires. At the landscape scale, this may cause an increase in chaparral as high-severity patches are converted from their initial vegetation type. This would provide few opportunities to re-create the late seral forest habitat used by the California spotted owl for core nesting and roosting areas.

California Spotted Owl Populations

While spotted owls are not considered highly vulnerable to direct impacts of climate change, the projected future conditions described above are likely to negatively impact California spotted owl populations by decreasing the amount of suitable habitat available. Additionally, barred owl populations have been growing in recent years in the Sierra Nevada and are projected to increase in the future (Keane 2017). Without intervention, a growing barred owl population is likely to cause a significant decline in the spotted owl population size in the future. Projections for future California spotted owl populations are fairly speculative, but recent trends in northern spotted owl

populations (Dugger et al. 2016) would suggest a declining population without active management and intervention.

Using Natural Range of Variation Information in this Document

The natural range of variation is the range of conditions in which the California spotted owl evolved and persisted prior to European settlement of California. The spatial arrangement of habitat elements and the structure, composition, and processes of Sierra Nevada forests are outside this range. Departure from the natural range of variation has reduced the abundance and diversity of important habitat elements and poses a serious risk of losing owl habitat to fire, insects, disease, and drought. Restoring forest composition, structure, and processes based on reference conditions is linked to greater resilience to wildfire, climate change, and other stressors (Stephens et al. 2016, Larson et al. 2013, Kalies and Yocom Kent 2016).

Natural range of variation values are generally derived from an era of relatively cool, moist conditions. As noted in the “Climate Drivers” section, climate models project increasing temperatures and an increase in the frequency and strength of drought events. Given projections of future conditions, natural range of variation values should not be used as a targeted endpoint but rather as a starting point for movement towards a future range of variation. While we would ideally move conditions directly towards those that will be supported under the future range of variation, future range of variation is still an emerging concept and reference models are not yet widely available (Haugo et al. 2015). Natural range of variation values are a useful starting point for restoring Sierra Nevada forests toward conditions that will be more resilient in a warming climate (Stephens et al. 2013, Haugo et al. 2015). Many natural range of variation values were derived from studies in contemporary reference landscapes and from historic information sources, so they may represent resilient forest ecosystems under current warming climate conditions.

This conservation strategy focuses on the forest characteristics and natural range of variation values most important for ecosystem restoration to retain and promote California spotted owl habitat. The natural range of variation information in this section and section 6 should be supplemented by new research or local science-based information that provides more site-specific information on historic or potential future conditions.

Natural range of variation values generally include a range from a low number to a high number. These ranges are the product of different scientific studies yielding different results based on different methods and study areas at varied latitudes, elevations, aspects, stages of ecological succession, and topographic positions yielding different results based on different climates, ecological, and biophysical characteristics.

In using natural range of variation values to develop management objectives, one should consider which values, or subset of values, in the range are the most logical for the area being managed, while recognizing particular site characteristics (for example, topographic position, soil type, elevation, aspect, and vegetation type) and the dynamics of natural disturbance regimes (fire, insects, disease, drought, windthrow, landslides, etc.). For example, on a low-productivity, dry site, high on a south-facing slope that would naturally have frequent, low-intensity fires, it may be most appropriate to manage toward the low end of the natural range of variation for tree density. In contrast, for a high-productivity, wetter site in a valley bottom with less frequent fires, it may be most appropriate to manage toward the higher end of the natural range of variation for tree density.

Quantitative natural range of variation values will not always provide the information needed to make decisions. In some instances, natural range of variation values may not be well understood for key attributes. In other instances, natural range of variation values may not be applicable to the specific area for which one is making a decision, given current constraints or conditions. When natural range of variation values are not available or are not applicable to the particular area, the historic range of conditions and the future range of conditions will need to be estimated. These estimates should be based on an understanding of the physical characteristics and disturbance regimes associated with pre-settlement forests.

Section 6. Process for Developing Draft Conservation Measures

The conservation measures are designed to achieve the desired conditions identified in section 3, given the past, current, and probable future conditions outlined in sections 4 and 5. They are also designed to meet the short- and long-term needs of the California spotted owl by conserving key habitat elements (goal 2), by increasing resistance and resilience of Sierra Nevada forests to multiple disturbances (goal 3), and by minimizing impacts of threats like the barred owl, disease, and rodentidcide use (goal 1).

The habitat-based recommendations in section 7 are intended to provide high quality nesting and roosting habitat and increase the resilience of that habitat. California spotted owls consistently select densely canopied forest stands with large and old trees for nesting and roosting. Conserving these features across the landscape is a key component of the strategy. Restoring landscape conditions toward the natural range of variation, should help retain and recruit owl nesting and roosting habitat in areas that are most likely to be resilient in the long term and that are widely distributed across the range of the species. However, in transitioning from current conditions to those consistent with the natural range of variation, an additional layer of protection is advisable for the core area of nesting and roosting habitat surrounding an owl's nest tree or activity center.

Restoring Sierra Nevada forests to, or at least moving them toward, the natural range of variation is a primary component of the California spotted owl conservation strategy. Restored forests provide two essential benefits to the species. They have the range of conditions in which the species evolved and persisted prior to European settlement, so they provide the necessary habitat. They are also more diverse and resistant and resilient to many disturbances, such as fire, insects, disease, drought, and climate change, thereby reducing the risk of losing essential California spotted owl habitat in the future. In some instances, managing toward the natural range of variation may not retain nesting and roosting habitat, especially if the habitat is located in areas that would have burned under a natural fire regime. In some locations, it may be necessary to retain dense forests that provide high quality habitat for owls, even though these areas are outside of the natural range of variation and may be more vulnerable to wildfires, bark beetle infestations, and other disturbances.

The habitat-based recommendations in section 7 are intended to provide high quality nesting, roosting, and foraging habitat and increase the resilience of all owl habitat. The recommendations focus on the four core components listed below. The combination of landscape-scale restoration and reserve areas is intended to provide resilient owl habitat that is broadly distributed throughout the Sierra Nevada and to ensure California spotted owls will thrive (assuming other threats, like barred owls, are minimized) without further need for forest restoration or specially managed reserves.

1. Protection of high-quality nesting and roosting habitat elements, focused primarily in owl protected activity centers
2. Development of high-quality nesting and roosting habitat elements where there is currently a deficit based on the natural range of variation and the biophysical environment is capable of supporting them
3. Natural range of variation-based restoration across the landscape to create diversity consistent with the biophysical environment, resilience of habitat to disturbance, and increased area of high-quality foraging habitat
4. Large-scale application of managed and prescribe fire to maintain dynamic ecosystem structure and function

The other recommendations in section 7 are designed to minimize the threats to California spotted owl long-term viability from barred owls, rodenticide, diseases, and climate change. Because these are emerging and evolving threats, the recommendations take an adaptive management approach with two main components: 1) further study and assessment of threat levels and potential mitigation measures and 2) efforts to remove or mitigate immediate threats as they arise.

Section 7. Conservation Measures

Given the scientific uncertainty surrounding natural range of variation values at different spatial scales and the variability of forest conditions across the California spotted owl's range in the Sierra Nevada, the conservation measures should be used as benchmarks and guidelines to help make management decisions. They are not a strict set of rules to be applied identically in all situations. Implementation of conservation measures must be considered in the context of local conditions, new information, and a changing climate. When the best available scientific information and local knowledge indicate species conservation objectives can be best achieved by actions that deviate from specific recommendations below, actions should be adjusted accordingly.

The conservation measures are designed to achieve desired conditions and meet the short- and long-term needs of the California spotted owl. The measures include four general strategies, each with a set of more specific actions. Each conservation measure is followed by the number of the objective it is designed to achieve (refer to pages 3 and 4).

Strategy 1. Conserve Key California Spotted Owl Habitat and Habitat Elements (Goal 2)

1. **Designate protected activity centers** to protect the most important nesting and roosting areas in occupied owl territories. (Objective 2A)

   When surveys show owls occupying a certain area, managers should designate a protected activity center. A protected activity center should generally include:

   a. Approximately 300 acres of high quality habitat (Berigan et al. 2012), in as contiguous arrangement as possible, informed by topography and biophysical conditions;

   b. the known or suspected nest stand;

c. the highest quality nesting and roosting habitat[2] near the known or suspected nest stand, even if it crosses management unit; and

d. the next best available habitat, in wetter, higher productivity sites.

Protected activity centers should include wetter, higher productivity sites bordering, or adjacent to, the known or suspected nest stand since these areas are most likely to sustainably support essential nesting and roosting habitat (Underwood et al. 2010). Delineation of protected activity centers should use available biophysical information, such as landscape management unit and climatic water deficit, to include the most sustainable locations of high-quality habitat. However, protected activity centers may also include habitat that is outside the natural range of variation and not likely to be sustainable over time at the patch and patch neighborhood-scales, as necessary to ensure near-term suitability. As additional high-quality habitat grows in more resilient locations (for example, north facing slopes and valley bottoms), protected activity centers may be adjusted to incorporate these areas and exclude the less resilient habitat.

2. **Maintain a dynamic protected activity center system at the landscape scale** to provide the greatest benefit to the owl and incorporate the natural disturbance regimes and dynamic nature of owl habitat (Objectives 2A, 3A)

Protected activity centers should be added to the system when monitoring or survey data indicate territorial occupancy by owls and retired when either they have not been occupied for an extended period of time or when significant physical changes have occurred to the area. A decision about non-occupancy should be based on at least three consecutive years of surveys (Wood et al. unpublished data) in the protected activity center in accordance with the monitoring and survey protocol. When a protected activity center is retired, it returns to general forest status where it may be re-designated at a later date or managed towards larger landscape natural range of variation objectives. The same is true for its associated territory.

In addition to retiring a protected activity center in response to non-occupancy survey data, retiring a protected activity center is warranted when the physical characteristics have changed enough that continued owl nesting is unlikely. To determine if a disturbance is significant enough to retire a protected activity center, consider whether basal area mortality of greater than 75 percent has occurred over more than 50 percent of the territory (Jones et al. 2016), or less than 50 acres of suitable nesting and roosting habitat remain in the protected activity center. Where disturbance has reached these thresholds, no surveys are required before retiring the protected activity center.

Protected activity center boundaries should be modified in response to significant changes in the physical environment or new data on owl use and occupancy. Habitat conditions within a 1.5-mile radius around a protected activity center should be evaluated when modifying boundaries. This roughly represents an owl's home range.

[2] Suitable nesting and roosting habitat incorporates, in descending order of priority within categories - Canopy layers: Two or more; Tree size: trees in the dominant and co-dominant crown classes averaging 30 inches in diameter at breast height or greater, trees in dominant and co-dominant crown classes averaging 24 inches in diameter at breast height or greater; Canopy cover: at least 70 percent canopy cover, at least 60 percent canopy cover, at least 50 percent canopy cover; CWHR class: 6, 5D, 5M, 4D, 4M. CWHR habitat types include: Red Fir (RFR), Sierran Mixed Conifer (SMC), White Fir (WFR), Ponderosa Pine (PPN), Eastside Pine (EPN), Montane Hardwood-Conifer (MHC), Montane Riparian (MRI), Jeffery Pine (JPN) , Lodgepole Pine (LPN), Subalpine Conifer (SCN), Aspen (ASP)

When an area of nesting and roosting habitat has been rendered unsuitable by a disturbance but the protected activity center likely remains viable, protected activity center boundaries should be modified to exclude the degraded area and augmented with other areas. The added areas should have equal or higher-quality habitat than the excluded area or the potential to become nesting and roosting habitat, and they should be adjacent or close to the protected activity center.

When new owl survey data indicate resident owls are using areas outside the protected activity center boundary, the boundary may be adjusted to include the most heavily used areas and exclude unused areas.

Boundaries may be modified during project planning to help implement restoration and resilience treatments, if the modified protected activity center contains nesting and roosting habitat of equal or better quality and includes known or suspected nest sites and important roosting sites. Preference should be given for modifications which add more mesic sites and remove drier sites

3. **Minimize risk of habitat loss associated with altered disturbance regimes**, including altered fire dynamics and increased insect outbreaks, through management around at-risk protected activity centers. (Objective 2E)

   When nesting and roosting habitat in a protected activity center are at significant risk of degradation or loss from disturbances originating outside the protected activity center, risk-reduction treatments outside the protected activity center should be implemented (Dow et al. 2016), even if the results of those treatments do not fully align with the patterns and stand characteristics expected under the natural range of variation. However, the treatments should be as consistent with the natural range of variation as possible. Prioritize treatments around protected activity centers with the highest severe wildfire risk, highest mortality risk (based on density and basal area thresholds), or both (see figures 8 and 9 below for examples) .

   If a protected activity center is in or near an area of high fire hazard, strategically placed landscape treatments, shaded fuel breaks, or both may be appropriate around the protected activity center. If a protected activity center is in or near an area at risk from bark beetles or drought (based on stand density and species composition), significantly reducing tree density outside the protected activity center may be appropriate.

   Fuel breaks immediately adjacent to the protected activity center should be located in the lower-quality owl habitat (for example, even-aged stands of smaller or medium sized trees) as feasible to protect the higher-quality habitat (for example, multiple-aged stands of larger trees). However, effectiveness of risk reduction should be the ultimate guide of fuel break placement. Continue and expand cross-boundary collaborations to increase fuel treatment effectiveness, including mechanisms like the forest fuels reduction memorandum of understanding signed in 2017 by the USDA Forest Service, National Fish and Wildlife Foundation, California Department of Forestry and Fire Protection, and Sierra Pacific Industries.

   Where local information on the future range of variation is available and suggests the natural range of variation is not sufficient to reduce risk from near future disturbance regimes, treatments to move the area around protected activity centers toward the future range of variation may be appropriate.

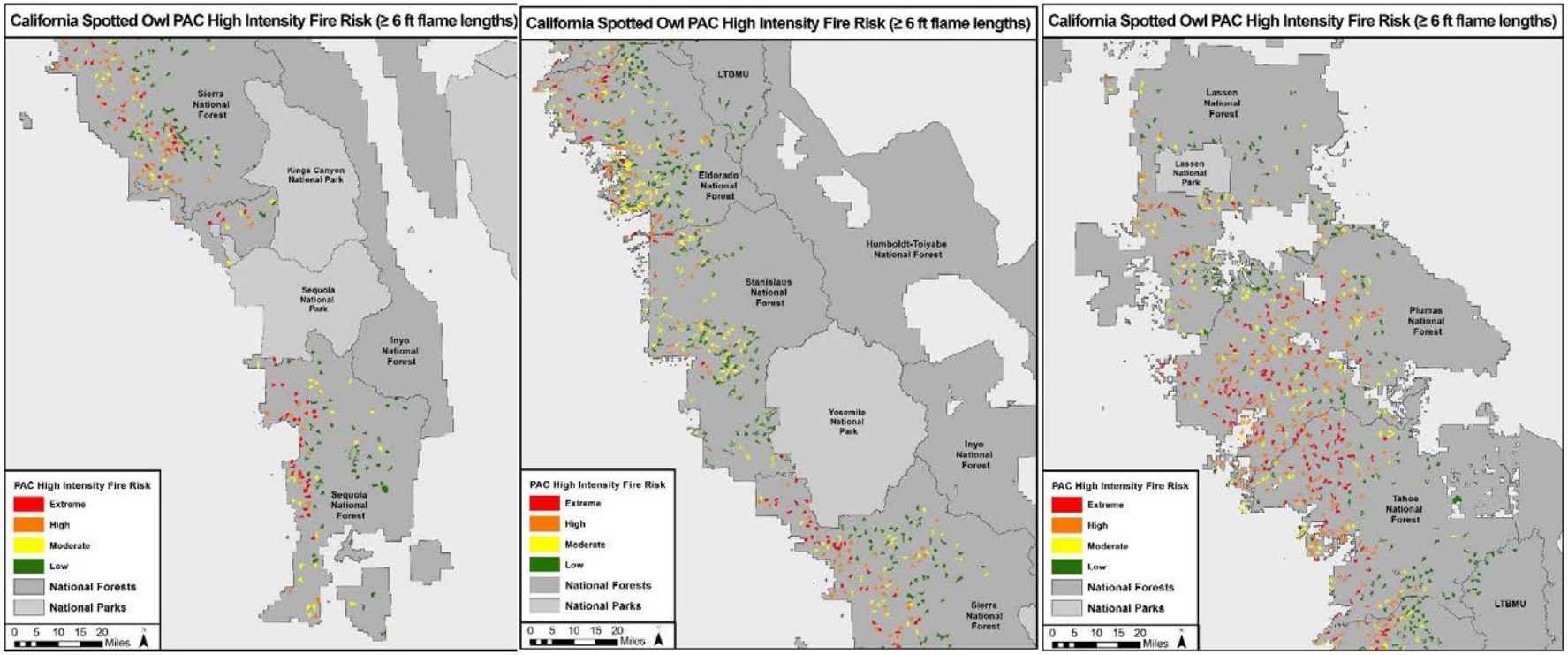

Figure 8. Protected Activity Center High Severity Fire Risk

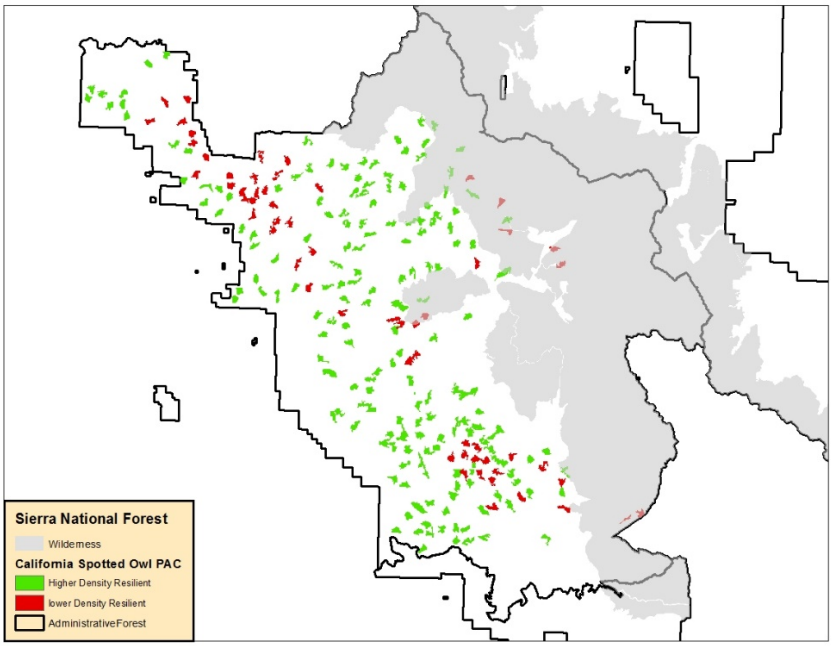

Figure 9. Example classification of protected activity centers at higher and lower risk of density related tree mortality on the Sierra National Forest[3]

4. **Minimize disturbance in protected activity centers**, including noise disturbance to owls during breeding season and physical disturbance to key owl habitat elements, while increasing resilience and sustainability of protected activity centers. (Objectives 1A, 2D, 2E, 3E)

   If restoration in protected activity centers is necessary, use available information on occupancy and resiliency (or departure from the natural range of variation) in prioritizing protected activity centers for treatment. Prioritization should preferentially avoid protected activity centers that have the highest likely contribution to near term owl productivity while increasing resilience where it is likely to have the largest positive impact on the protected activity center network[4]. Consider the risk of large high intensity wildfire to single or clustered protected activity centers, degree of departure from desired condition and natural range of variation, and occupancy and reproductive status and history. Prioritize ecological restoration of protected activity centers, and areas within protected activity centers, that have departed furthest from desired conditions and natural range of variation. Prioritize protected activity centers with the highest risk of high intensity wildfire, highest mortality risk, or both (see figures 8 and 9 above for examples). Within protected activity centers, design restoration to promote the greatest ecological resilience of the protected activity center network, while minimizing impacts to the activity center and maintaining high quality nesting and roosting habitat. Based on local conditions, select treatment type that will increase resilience while minimizing disturbance in protected activity center. Restoration and resilience treatments in protected activity centers should prioritize the use of prescribed fire and may include mechanical, prescribed fire, wildfire managed for resource objectives, and hand treatments.

[3] This figure is meant only as an illustrative example of potential schemes for classification of PACs at higher and lower risk of density related tree mortality. Figure values are based on stand density and percent maximum stand density index for pine mortality in the appropriate vegetation type.
[4] Use information developed in quantitative risk assessment currently underway (February 2018) by University partners.

Treatment prioritization

Priority based on resilience:

1. Least resilient and putting neighboring high quality areas at risk
2. Moderately resilient but putting neighboring high quality areas at risk
3. Most resilient

Priority based on occupancy and contribution to productivity:

1. Currently unoccupied and historically occupied by territorial singles only.
2. Currently unoccupied and historically occupied by pairs.
3. Currently occupied by territorial singles.
4. Currently occupied by pairs.
5. Currently or historically reproductive.

Treatment design by treatment type

Fire (and accompanying hand treatments) is a primary tool for achieving restoration goals within protected activity centers (U.S. Fish and Wildlife Service 2017). Prescribed fire and wildfire managed for resource objectives are likely beneficial in protected activity centers when maintained at low intensity (flame lengths less than 4 feet) and moderate intensity (flame lengths 4 to 8 feet) so that overstory conditions are not significantly modified. Where surface and ladder fuels need to be reduced, low-intensity fire treatments should be utilized. Areas treated with a combination of thinning and prescribed fire are likely to burn at lower severities when fire occurs (Lydersen et al. 2017). Further, following mechanical treatments with fire increases treatment efficacy in moving conditions towards the natural range of variation (North et al. 2007).

The nest structure, tree, or snag is an important resource in the protected activity center, and it should be protected throughout any treatments. During prescribed burns, all efforts should be made to protect the nest tree (if known) by doing one or more of the following where feasible:

- Raking litter and duff away
- Building line (excluding tree removal) around the base using a radius away from the tree equal to the tree's height
- Using chainsaws to remove ladder fuel directly in contact with the nest tree

Adjacent large trees that create significant protection over the nest cavity should be protected by constructing fire line around the tree(s) or lightly backfiring out from the nest.

If the protected activity center is heavily loaded with ground and ladder fuels and there is concern any planned ignitions will burn too intensely, plan multiple entries. Use spring or wet season burns for the first (and second, if needed) entry to initially reduce fuel loading.

When using fire, establish, and adhere to, mitigating procedures to minimize impacts to owls, especially if burning during the breeding season:

- When constructing fire lines, strive to avoid large snags where feasible (snag characteristics are described on page 48)
- Try to avoid increasing canopy openings/gaps in the 10-acre area around the nest site
- When possible, direct smoke away from the nest cavity
- Limit thick patches of ground-level stagnant smoke at night by:
    - taking topography into account;
    - taking advantage of down-canyon winds to move smoke;
    - keeping flame lengths lower near the nest structure; and
    - minimizing the amount of time fire is burning close to the nest structure.

Use hand treatments where appropriate to maintain or improve habitat quality (for example, multi-layered structure, diverse diameter classes, moderate to high canopy cover). The treatments should have minimal impact on stand overstory structure, reduce risk to key habitat, reduce lower strata (6 to 60 feet high) cover, facilitate use of prescribed fire, or some combination of these.

Using mechanical treatments (see glossary) in protected activity centers should be guided by:

- existence of adequate monitoring/survey information [*see monitoring section*];
- development of a protected activity center prioritization scheme [*see above*]; and
- information from the quantitative risk assessment currently underway by University of Wisconsin, Madison and University of California, Merced.

When mechanically treating within protected activity centers, don't treat the highest-value, most used, or most resilient stands. Prioritize stands/patches for treatment (Lehmkuhl et al. 2015) based on the following:

- How much the owls use the area or the existence of a nest. Areas used most heavily by owls and those associated with an owl nest should receive a retention emphasis. Focus resiliency treatments in areas of little to no use.
- Habitat sustainability and the potential for conveying natural disturbances. Prioritize treatment in areas where habitat is likely not sustainable or could convey natural disturbances across the landscape in ways that jeopardize large patches of owl habitat. Use available disturbance progression models to determine this.
- Available habitat nearby. Stands within the protected activity center may receive higher priority for treatment if there are nearby areas that are currently habitat, likely to sustain owl habitat, or likely to become habitat within a short time (for example, 20 years).
- Potential for dispersal. Prioritize treatment in stands that are not likely to promote successful dispersal between existing home ranges or territory clusters, as indicated by any future available connectivity modeling.
- Habitat function after treatment. Prioritize treatment in areas that will retain habitat function after treatment and still meet the restoration objective.

Mechanical treatment should adhere to the following recommendations:

- design treatments for individual trees, clumps of trees, and openings and focus on removal of smaller trees (less than 60 feet tall)
- apply mechanical treatment to no more than one third of the protected activity center
- do not remove overstory trees or trees larger than 24 inches in diameter at breast height
- do not treat within the 10 acre area surrounding the nest

Treating roost trees with semiochemicals (for example, pheromones) to reduce risk of bark beetle infestation may be appropriate during periods of elevated beetle populations in adjacent areas and/or during extended drought.

Use limited operating periods during the early breeding season (March 1 to July 15), when and where owls are actively nesting, to minimize noise disturbance to California spotted owl reproduction. Limited operating periods may be modified or waived where surveys indicate absence of nesting owls. If active nesting cannot be verified or disproved, apply the limited operating period to the former year's nest site (where known) or to the entire protected activity center (where previous year's nest not known):

Chainsaws and other power equipment

- Avoid using power equipment like chainsaws or pole pruners within 300 feet of the nest site or known roost site during the early breeding season

Roads, vehicles, and mechanized equipment

- Avoid road construction or extensive heavy mechanized equipment activity within a quarter mile of the nest, or known roost site, during the early breeding season

Helicopters

- Minimize helicopter flights over nests (and protected activity centers if possible)
- Avoid flying low or hovering over nests (and protected activity centers if possible)
- Choose flight paths that avoid nest areas (and protected activity centers if possible)
- Establish landing zones at least one half mile away from the nest

Fire

- Don't conduct pre-burning activities (for example, fire line construction) within 300 feet of the nest site during the early breeding season
- Don't burn within a quarter mile of the nest during the breeding season (approximately March 1 through August 15) if owls are nesting that year. This restriction may be waived, where necessary to facilitate the benefits of using early season prescribed fire, in up to 10 percent of protected activity centers per year in a given management unit

5. **Designate territories and retain and recruit areas of high canopy cover-large tree habitat at the patch and patch neighborhood scales—while promoting vegetation diversity within each territory** (objectives 2A, 2B, 2D).

Where a protected activity center is designated, also designate a 1,000-acre (northern and central Sierra) or 800-acre (southern Sierra) area as the associated owl territory. The territory is contiguous, includes all acres inside the protected activity center, and should contain

diverse structural and seral conditions to facilitate both nesting and roosting and foraging. The territory may be mapped at various levels of ecological relevance, dependent on available information:

- Where no additional reliable vegetation, biophysical, or owl use information is readily available, map a territory as a circle around the activity center (nest tree)
- Where topographic (for example, landscape management unit) and fine scale vegetation information (for example, LiDAR) are available, adjust territory boundaries to include adjacent large-tree and high canopy cover habitat where it exists in likely sustainable locations (for example, drainage bottoms and north facing slopes), as well as more open foraging habitat where it exists in sustainable locations (for example, south facing slopes that have recent fire history), and to exclude areas where vegetation traits are less sustainable (for example, dense, smaller trees on ridgetops)
- Where extensive owl use information is available, adjust territory boundaries from the above area to include areas of high owl use and exclude avoided areas

Both moderate and high canopy cover are important at the territory scale for occupancy, survival, and reproduction (Tempel et al. 2016, J.D. Wolfe and J.J. Keane personal communication, USFWS 2017). Habitat with both large trees and high canopy cover is the most important predictor of occupancy and persistence, and habitat with large trees and moderate canopy cover is also positively associated with occupancy and persistence (Jones et al. 2017). On the other hand, recent work suggests selection against smaller tree, high-canopy habitat at higher elevation sites (more than 4,250 feet; M. Raphael, personal communication), and against lower-strata (less than 53 feet) tree cover across sites (North et al. 2017).

Generally, each occupied territory[5] should consist of at least 40 to 50 percent of the highest quality nesting and roosting habitat (defined here as large tree high cover; large tree medium cover; medium tree high cover; and medium tree medium cover habitat[6] in descending order of priority). The remainder of the territory should consist of a mosaic of nesting, roosting, foraging, and dispersal habitat, informed by site conditions such as topography, climate, latitude, and site productivity. The long-term desired condition for each occupied territory is that at least 20 percent of the territory has habitat characterized by both high canopy cover and large, tall trees (Jones et al. 2017, North et al. 2017), and at least 10 percent of territory has habitat characterized by large, tall tree moderate canopy cover habitat. In the near term, for those occupied territories that do not currently meet the desired condition for large tree habitat, retention of additional medium tree habitat will be necessary to make up the remainder of the 40 to 50 percent as the territory moves toward desired conditions. Decisions regarding the retention of medium and large trees and medium and high canopy cover within a territory should be guided by the natural range of variation, latitude, elevation, landscape context, and location information about the owls. Generally, high canopy cover is more important to owls at higher latitudes (Jones et al. 2017) and higher elevations (Jones et al. 2016). Relatively more shrub patches and early-seral stage forest conditions at low elevations (less than 1,400 meters or less than 4,500 feet) may promote wood rat populations (Wilson and Forsman 2013, Jones et al. 2016) while more closed canopy, later seral conditions may

[5] Occupied territory is assumed for occupied protected activity center (unoccupied protected activity center indicates unoccupied territory)

[6] Note: these types are currently defined using percent canopy cover and quadratic mean diameter, based on GNN data, as in Jones et al. 2017. Before finalization of this Strategy, types will need to be translated to a corporate data source that is updated regularly.

promote flying squirrel populations at higher elevations (more than 4,500 feet; Jones et al. 2016).

- Maintain or promote high canopy cover in areas dominated by large trees or in areas likely to develop and sustain large trees in the future.
- Maintain or promote moderate and high canopy cover and denser habitat in the wetter, more productive sites near known or suspected nest stands. These conditions are unlikely to be sustainable in drier areas, particularly those with higher mean annual climatic water deficit (Young et al. 2017).
- Maintain or promote moderate and high canopy and larger trees in areas likely to provide habitat connectivity in and between protected activity centers.
- Maintain or promote more higher canopy cover (more than 55 percent) tall tree and co-dominate tree habitat in protected activity centers and nest stands, with more even representation of many different structure and canopy cover classes at the territory scale and beyond (North et al. 2017).
- In territories needing restoration that do not yet meet the desired condition, do not reduce canopy cover or quadratic mean tree diameter in the existing large tree-high canopy cover habitat, regardless of habitat location. Maintain vertical structure diversity and multiple size classes in this habitat while reducing crown fire risk as necessary through ladder fuel reduction.

6. **Retain and recruit large, old, and structurally-complex trees and snags**, consistent with abundance and distribution at the stand/patch and neighborhood-scales under the natural range of variation to provide owl nesting and roosting habitat and to benefit the northern flying squirrel, a primary owl prey species (objective 2C). Managing for landscapes that contain tall trees, which are more fire resilient, will both increase owl habitat suitability and reduce loss of owl habitat under increasing disturbance regimes (North et al. 2017). See strategy 2 measure 2 (page 51) for more information. See table 1 for a description of tree diameters used as points of reference in this document.

   Where large, old, structurally complex trees are at risk due to competition, drought, insects, pathogens, and fire, consider treatments to reduce stand densities around the trees to reduce competitive stress (Fettig et al 2007, McDowell and Allen 2015, Young et al. 2017), reduce smaller ladder fuels to reduce fire risk, or some combination of the two, while retaining representation in three or more tree size classes. Promote development of large, old, structurally complex trees elsewhere through similar treatments. Reduction of sub-canopy and intermediate-size trees may reduce water competition, increasing large tree resilience, while also opening up more growing space to accelerate tree growth (North et al. 2017) and retaining three or more size classes.

   At the patch neighborhood scale, retain sufficient trees more than 24 inches in diameter at breast height to provide large and very large trees in the future, consistent with the distribution and abundance of such trees under the natural range of variation. Emphasize the retention of large and very large trees in areas where biophysical conditions are likely to sustainably support both high canopy cover and large trees in the future (U.S. Fish and Wildlife Service 2017). Retain all tall and co-dominant trees greater than 24 inches in diameter at breast height within the nest site (10 acres surrounding the nest) and protected activity center.

Retain and protect all live conifers greater than 30 inches in diameter at breast height unless they are an impediment to attaining restoration or resilience goals. Preferentially retain trees greater than 35 inches in diameter at breast height because 75 percent of owl nests in conifers[7] have been in trees this size (J.J. Keane unpublished data), and deficits in trees greater than 36 inches in diameter at breast height have been recorded rangewide (see section 5). Preferentially promote and maintain trees in the upper strata (more than 160 feet tall), which owls select strongly for at all scales (North et al. 2017). Active reduction of stem density in the lower strata (less than 60 feet tall) should be pursued in large and tall tree areas to protect these larger trees (North et al. 2017), while retaining multiple size classes and canopy layers. Exceptions to this recommendation should be rare (see strategy 2, measure 2 for more information).

Retain and recruit large snags consistent with the natural range of variation. Snags should be irregularly distributed in clumps and individuals, according to site conditions and natural disturbance dynamics. Retain the largest, oldest, and most decadent live trees as a source of future large snags. To meet fuels-reduction objectives, remove smaller snags in excess of what would be expected under the natural range of variation (Knapp 2015).

Consider the following characteristics when assessing the value of snags for California spotted owls:

- Moderate signs of decay with large pieces of bark pulling away from the bole that causes safe spaces or pockets for bats and flying squirrels to roost or den. Bats and flying squirrels are owl prey species.
- Snags with small to large cavities, especially if they are protected by adjacent overhanging canopy.
- Whitewash around the base or on the snag, indicating it is currently being used.
- Snags with large (5 inches by 3 inches), squared-off, oval-shaped cavities typically created by pileated woodpeckers. These cavities may be important as future nesting structures because decay quickly enlarges these cavities for owls.
- Large snags near perennial water. These snags are important to principal spotted owl prey.

Strategy 2. Restoration of Resilient Forest Conditions Guided by the Natural Range of Variation (Goal 3)

Forest management can help move forests used by owls towards the natural range of variation at the landscape (10,000 to 100,000 acres), neighborhood (1 to 10,000 acres) and stand or patch (tens to hundreds of acres) scales. Mechanical harvest and thinning and fire treatments can modify seral stage and canopy-cover diversity; reduce forest density; retain and recruit large and old trees, snags, and downed logs; increase the proportion of fire-resistant tree species; increase understory diversity conditions to include more forbs and shrubs and less surface fuels; and change the amount and types of fire on the landscape. Active forest management is necessary to provide diverse and resilient habitat for the California spotted owl now and in the future (Stephens et al 2016a, b).

[7] Calculations exclude giant sequoias, as owls generally nest in much larger sequoias which would lead to a larger tree size benchmark, but benchmark should include retention of sequoias.

1. **Increase vegetation diversity** at the landscape, neighborhood and stand/patch scales to approximate the distribution and pattern of seral stages and canopy cover classes under the natural range of variation. Restoring the proportion and pattern of seral stage and canopy-cover classes to the natural range of variation should improve owl nesting, roosting, and foraging habitat and reduce the risk of losing key habitat to severe disturbances (objectives 3A, 3B).

   At the landscape scale, manage towards a mix of seral stages and canopy conditions consistent with the natural range of variation. This will generally mean increasing the amount of open canopy habitat in all seral stages and the amount of late seral stand conditions (open or closed canopy) to get a patchy distribution of diverse stand types. In planning the size and distribution of seral stage and canopy cover class, consider the potential forest type within the zone (yellow pine, dry mixed conifer, or moist mixed conifer; see page 28), effects of site conditions (topographic position, soil type, elevation, aspect, and vegetation type) and disturbance regimes (fire, insects, disease, drought, windthrow, landslides, etc.) (Stine et al. 2014).

   Based on the likely patterns of historic forest conditions listed below, the landscape scale should have a patchwork of relatively open canopy areas over the majority of the landscape, interspersed with early seral and closed canopy areas. The average canopy cover should range from 17 to 49 percent (Safford and Stevens 2017). Yellow pine should contain more of the open canopy categories and moist mixed conifer more of the closed canopy within the ranges described below.

   - Early seral:[8] 5 to 15 percent
   - Open canopy mid seral: 15 to 30 percent
   - Closed canopy mid seral:[9] 5 to 15 percent
   - Open canopy late seral: 25 to 45 percent
   - Closed canopy late seral: 5 to 20 percent

   Manage for relatively more closed canopy late seral conditions at higher elevations, and more early seral and open canopy conditions with increases shrub patches at lower elevations. Shrub patches and early-seral stage forest conditions at low elevations may promote wood rat populations (Wilson and Forsman 2013, Jones et al. 2016). Closed canopy, later seral conditions may promote flying squirrel populations at higher elevations (Jones et al. 2016).

   At the neighborhood and stand or patch scales, manage for within-stand and multi-stand diversity, consistent with site characteristics and the variable influences of natural disturbances. Stands should have a pattern of individual trees, various sizes of clumps of trees, and openings and contain three or more size classes. These patterns range in size,

[8] Early seral corresponds to CWHR size class 3 and below (average tree size less than 12 inches in diameter at breast height), mid seral corresponds to CWHR size class 4 (average tree size 12 to 24 inches in diameter at breast height), and late seral corresponds to CWHR size class 5 (average tree size 24 inches or greater in diameter at breast height).

[9] Closed canopy conditions, as defined in these models, range from 50 to 100 percent canopy cover for mixed conifer and westside yellow pine (40 to 100 percent for eastside pine). This roughly corresponds to CWHR densities M and D (40 to 100 percent).

configuration, and frequency based on the natural range of variation as described below (Lydersen et al. 2013, Kane et al. 2013, 2014).

- Openings would be less than 3 acres in size and most would be less than a quarter of an acre. There would be 1 to 3 openings or gaps per acre with an average of 2 to 2.5. These small openings would make up 20 to 50 percent of a stand (average would be 35 percent), and their shapes would be irregular.
- Small clumps of trees would have 2 to 4 trees; medium clumps of trees would have 5 to 9 trees; and large clumps of trees would have more than 10 trees. Clumps of trees would make up 40 to 70 percent of a stand. Individual trees would make up 5 to 10 percent of a stand and would be primarily pine and oak species. Not all clump and gaps sizes would be present in every stand or patch, but would be represented across stands at the patch neighborhood scale.[10]

In determining the appropriate pattern of individual trees, clumps of trees, and openings in the natural range of variation for a given stand, account for site conditions (topographic position, soil type, elevation, aspect, and vegetation type) and natural disturbance regimes (for example, fire, insects, disease, drought, windthrow, landslides, etc.). Based on fire regimes, openings are likely to be larger and more frequent on low-productivity, dry, south slopes and ridge-tops and smaller and less frequent in high-productivity, moist valley bottoms. Ridgetops and south-facing slopes should generally exhibit a higher proportion of trees as single individuals, a smaller proportion of trees as tree clusters, and a smaller number of trees per cluster. The drier portions of the landscape should also have more variation in the distance between tree crowns.

At the stand scale, in moister areas, manage for some large clumps (more than 10 trees) with multiple, overlapping canopy layers formed by large trees or complex structure with different ages and sizes of trees, to develop additional high quality spotted owl habitat for the future.

2. **Retain and recruit large, old, and structurally-complex trees and snags**, consistent with abundance and distribution under the natural range of variation to provide owl nesting and roosting habitat and to benefit the northern flying squirrel, a primary owl prey species. (objective 3D) Managing for landscapes that contain tall trees, which are more fire resilient, will both increase owl habitat suitability and reduce loss of owl habitat under increasing disturbance regimes (North et al. 2017). See strategy 1, measure 5 above (page 48) for more information.

   Low-productivity sites and dry sites are likely to support fewer large and very large trees and snags than high-productivity and wetter sites, and patterns vary within a range as listed below (Collins et al. 2015, Stephens et al. 2015, North et al. 2009, Agee 2002, Safford and Stevens 2015, Stephens 2004, Stephens et al. 2007, Dunbar-Irwin and Safford 2016):

   - Average large trees per acre: 3 to 30. Values should be averaged at the stand or patch scale. Large is defined as more than 24 inches in diameter at breast height in yellow pine-mixed conifer. Wetter and more productive sites will support averages at the high end of

[10] While definitions for clumps and individual trees may vary, the main objective should be to manage for a broad diversity of stem distributions, with a range of openings and variable sized groups, similar to what would have resulted from a complex and random set of disturbances and site characteristics played out over centuries.

the range and drier less productive sites will support averages at the low end of the range, with much variation in between.

- Average very large trees per acre: 1.5 to 8. Values should be averaged at the stand or patch scale. Very large is defined as more than 36 inches in diameter at breast height in yellow pine-mixed conifer.
- Average snags per acre: 1.6 to 5. Snag distribution and abundance is highly variable and should be averaged at the stand or patch scale. Snags are defined as more than 6 inches in diameter at breast height (15 centimeters). Average snag size: 30 inches in diameter at breast height.
- To promote larger tree size on the landscape, manage towards an average and median tree size at the neighborhood scale of more than 22 inches and 27 inches, respectively, with high variability between patches.

Deciding which trees should be removed or promoted will be governed by natural range of variation values and stand-specific structure and composition goals addressed in other recommendations. Recruiting more large trees and increasing their ability to resist future drought events and increasing temperatures will mean reducing competition, particularly on drier sites (Young et al. 2017). Exceptions to the recommendation to retain all conifers greater than 30 inches in diameter at breast height would apply only to trees outside protected activity centers and up to 40 inches in diameter at breast height.[11] Exceptions to the recommended 30 inch diameter cap should be based on natural range of variation restoration objectives such as the following:

- In low- to mid-elevation, pine-dominated, mixed-conifer forests where the removal of shade-tolerant trees more than 30 inches in diameter at breast height is necessary to promote the growth, vigor, and development of shade-intolerant species of approximately equal or larger size to more effectively meet species composition and forest structure restoration goals. Treatments should ensure large trees and tree species diversity are maintained into the future (Hessburg et al. 2016).
- When using natural or artificial regeneration in pine-dominated forest types, removal of select shade-tolerant trees greater than 30 inches in diameter at breast height is necessary to promote the establishment, growth, and development of stands with 3 or more well-defined size and age classes (Zald et al. 2008, York et al. 2004). This exception should not be used to remove shade-tolerant trees greater than 30 inches to eliminate the shade-tolerant seed source. It should be used to provide naturally regenerating, shade-intolerant tree species that can establish and grow in portions of the stand (for example, irregular-shaped, small canopy gaps in the natural range of variation).
- Removal of trees more than 30 inches in diameter at breast height surrounding rust-resistant white pine to improve the growth and vigor of these trees and maintain this valuable genetic resource on the landscape (Hessburg et al. 2016).

[11] Trees greater than 40 inches are generally lacking in historically cut-over stands (Taylor 2004), suggesting that those present today pre-date logging and largely pre-date fire suppression. Further, trees greater than 40 inches (particularly pines) may be less abundant today than historically, even in unlogged stands, likely due to elevated moisture stress and drought related mortality since fire suppression commenced (North et al. 2007, Lutz et al. 2009, Scholl and Taylor 2010). Roughly 70 percent of owl nest sites in conifers are in trees greater than 40 inches (J.J. Keane unpublished data). Thus, trees greater than 40 inches should not be removed.

- Removal of conifers more than 30 inches in diameter at breast height may be prescribed under aspen, oak, or meadow restoration treatments.

3. **Reduce tree densities** to approximate the range of densities that would have been likely at the stand/patch and neighborhood-scales under the natural range of variation and are likely to be more sustainable under a changing climate. Restoring stands to densities consistent with the natural range of variation should reduce the risk of losing important owl habitat to severe disturbances and may increase the abundance and diversity of owl prey species (objectives 3B, 3C, 3D, 3E).

   Where long-term fire exclusion has resulted in stand densities outside the natural range of variation, this will generally mean reducing densities in small to medium size classes across seral stages and canopy-cover classes, while retaining representation of at least three age/size classes where they exist. The lowest tree densities would be in open-canopy, late-seral stands on low-productivity, dry sites. The highest densities would be in closed-canopy, early- and mid-seral stands on high-productivity, wetter sites.

   In the yellow pine and mixed-conifer zone, historical densities likely ranged from 24 to 132 overstory trees per acre (60 to 328 trees per hectare), with an average of 64 trees per acre (159 trees per hectare) averaged at the stand or patch scale (Safford and Stevens 2017). At the neighborhood scale, manage densities within the natural range of variation based on the biophysical environment and site productivity. At the landscape scale, manage densities based on potential vegetation types within this zone, with yellow pine forests supporting densities on the lower end and moist mixed conifer forests on the higher end of the natural range of variation.

   Areas of low live basal area are more resistant to substantial mortality under high climatic water deficit conditions. Low live basal area is approximately 44 square feet per acre or 10 square meters per acre (Young et al. 2017), a value much lower than would support owl nest or roost stands. This suggests that managing areas of very high climatic water deficit conditions for owl nesting habitat or high-density stands is unlikely to be sustainable in the long term and should be reconsidered. New nesting habitat and denser stands should be promoted and developed in areas of lower climatic water deficit to ensure sustainability.

   Remove trees in overrepresented size classes (frequently smaller or intermediate classes depending on stand conditions) and retain the largest trees in a stand. Retain a diversity of size and age classes consistent with the natural range of variation, providing for multiple distinct size classes. Retain sufficient smaller trees to provide habitat diversity and recruitment of future large trees.

   Use stand density index to help guide stand density management, depending on local site conditions and short- and long-term objectives. Examples are listed below:

   - In stands managed for mid- and late-seral, closed-canopy conditions, maintain stand densities between the lower and upper limit of full site occupancy – approximately 35 to 60 percent of maximum stand density index. This will maintain stand vigor and avoid extensive density-induced mortality (Long et al. 2004, Long and Shaw 2012, Lehmkuhl et al 2015). Consider radial thinning of subdominant trees around desired legacy trees or clumps of legacy trees to reduce drought stress and improve resilience.
   - In stands managed for mid- and late-seral, open-canopy conditions, reduce stand densities to the lower limit of full site occupancy or below – approximately 35 percent or less of

maximum stand density index. This will help develop large-diameter trees with full, open-grown crowns (Long et al. 2004, Long and Shaw 2012, Lehmkuhl et al 2015). Include small openings for seedling establishment and fuel discontinuity to produce the full range of size and age classes expected within the natural range of variation.

- Ensure maximum stand density index values (which vary by species) and tree density are selected based on desired and historical species compositions, rather than current species composition, especially on highly departed sites.

4. **Restore the approximate proportion and distribution of tree species** on the landscape consistent with the natural range of variation and potential vegetation type. Increasing the abundance and distribution of fire-resistant pine trees will help restore disturbance that is compatible with owl habitat development (Objective 3C). This will generally mean retaining and recruiting more shade-intolerant and fire resilient and resistant species (ponderosa pine, sugar pine, Jeffrey pine, and black oak[12]) and removing a higher proportion of shade-tolerant species (white fir, incense cedar, and Douglas fir).

   In the yellow pine and mixed-conifer zone, the overstory of open-canopy, mid- and late-seral stands and regeneration in early-seral stands should be dominated by shade-intolerant pine and oak species. Shade-tolerant species should remain a minor to subdominant component in these stands, and species diversity should be promoted. Such stands will generally be located on drier sites with a higher natural fire frequency, intensity, or both. In closed-canopy stands generally located in wetter areas, a more even mix of conifer species (including stands dominated by shade-tolerant species) is appropriate in the overstory and understory.

   At the stand or patch scale, if conditions indicate a current mixed-conifer stand was likely a yellow pine stand under the natural range of variation, remove some shade-tolerant trees to restore the stand to yellow pine dominance. Do not remove trees larger than 40 inches in diameter at breast height and leave some smaller individuals and groups of shade-tolerant trees as well, providing for at least three size/age classes.

   Remove smaller trees and fire-sensitive species that would not have survived under a natural fire regime.

5. **Restore the composition, pattern, and structure of understory live vegetation and woody debris**, consistent with the natural range of variation. This should improve the abundance and diversity of owl prey species, reduce the risk of owl habitat loss from fire, and increase the potential to restore natural disturbance dynamics (objectives 2E, 3B, 3C, 3D, 3E). This will generally mean increasing the diversity and abundance of forbs and shrubs in the understory and reducing the amount and continuity of duff, litter, and woody debris.

   Manage the understory of mid- and late-seral areas for a patchy distribution of shrubs, forbs, tree regeneration patches, and bare ground to increase diversity, reduce fuels continuity, and provide habitat for owl prey species. Management of understory vegetation and fuels through prescribed burning or other approaches (for example, managed fire, mechanical treatment) is often required to achieve these conditions, especially when overstory treatments cause increased surface fuel loading.

[12] Sugar pine is partially shade tolerant, and black oak shade tolerance declines over time, with seedlings and saplings exhibiting some shade tolerance and larger trees exhibiting substantially less shade tolerance.

At the stand scale, manage for patches of coarse woody debris and thicker litter layers interspersed with areas of shrubs and open areas with only ground vegetation such as forbs and grasses. Preferentially retain logs in the largest size classes.

Manage stands for relatively low levels of surface fuels, relatively low but variable levels of coarse woody debris, and variable densities of logs across the landscape. This should result in distribution and volume of duff, litter, and woody debris consistent with the natural range of variation (Stephens et al. 2004, 2007; Brown et al. 2003)

Prescribed fire, managed fire, or both should be used to reduce the distribution and volume of duff and litter, with some pre-fire duff removal around important trees. While there are no estimates for the historic abundance and distribution of duff and litter, it is widely agreed the current abundance and continuity of duff and litter are far above the natural range of variation due to fire suppression. Stands should be managed to reduce the abundance and continuity of duff and litter, keeping in mind site conditions and the variability of natural disturbance regimes. For example, duff, litter, and small woody debris are likely to be more abundant and continuous on wetter, more productive sites. Some benchmarks and ranges for surface fuels are included below (values should be averaged at the stand or patch, not the acre, scale):

- Generally manage for relatively low levels of surface fuels (1-hour to 1,000-hour fuels), averaging 5 to 10 tons per acre, largely occurring in 1,000-hour fuels, and varying widely between moister and drier sites (Brown et al. 2003, Stevens and Safford 2017)
- Where managing to provide additional woody debris for wildlife habitat (for example, within protected activity centers and connecting drainages): manage for slightly higher, but still highly variable, levels of coarse woody debris, averaging 5 to 20 tons per acre of coarse woody debris (logs larger than 3 inches in diameter) (Brown et al. 2003). Provide for an average of 3 to 5 logs per acre for logs larger than 20 inches in diameter (Lydersen and North 2012)
- Log density varies widely across the landscape, with some patches of high abundance on wetter, more productive sites and others with lower densities on drier, less productive sites.

6. **Restore natural disturbance dynamics** consistent with the natural range of variation to help shape and maintain resilient forests. Restoring natural disturbance regimes will presumably benefit the owl by creating and maintaining forest conditions similar to those in which the owl evolved and that are likely to persist in the future. Restoring natural disturbance regimes will create a dynamic and diverse mix of nesting, roosting, and foraging habitat and diverse and abundant habitat for prey species (objective 3E). This will generally mean managing for more low- and moderate-severity fires, fewer high-severity fires, and less bark beetle- and drought-induced tree mortality. However, some tree mortality is necessary to produce a supply of snags and downed logs.

   Use prescribed fire and managed fire to create a mosaic of fire effects consistent with the natural range of variation (U.S. Fish and Wildlife Service 2017). Manage for a matrix of low-severity burned areas intermixed with small-to-moderate patches of unburned and moderate-severity burned areas and dispersed high-severity areas. When developing prescribed fire and managed fire intervals, consider the natural fire return interval and fire rotation.

   Base fire restoration efforts on departures from the natural range of variation, as indicated by planning tools like the fire regime interval departure database. Areas with the highest

departure from the natural range of variation, with a high fire regime interval departure condition class of 2 or 3, could be targeted for wildfire reintroduction, assuming topography, weather, and fire risk patterns are conducive to achieving this objective (North et al. 2015, Meyer 2015). Areas mildly departed from the natural range of variation could be prioritized for prescribed fire, particularly in areas where wildfire reintroduction poses a greater risk to high-value resources and assets.

Design prescribed fire treatments for low and moderate severity, with small areas of high severity as feasible. Confine treatments to the understory with only occasional torching of single trees or small groups of trees. Treatments should remove understory vegetation and consume forest litter and woody debris (Safford and Van de Water 2014). Desired conditions approximate the proportions described below:

- Approximately 10 to 30 percent of the area in a fire perimeter is unburned. Thirty to 60 percent is burned at low severity. Fifteen to 35 percent is burned at moderate severity (25 to 75 percent basal area mortality). One to 10 percent is burned at high severity (more than 75 percent basal area mortality; Mallek et al. 2013; Collins and Stephens 2012).
- High-severity patches are generally less than 10 acres, with an average of 8.5 acres (Show and Kotok 1924, Collins and Stephens 2010; North et al Assessment) and a maximum patch size of 250 acres or less (Collins and Stephens 2010; Miller et al. 2012; Safford 2013). In known owl territories, high-severity patch sizes should generally be less than 10 acres, with a maximum patch size up to 100 acres to minimize long-term impacts on habitat (Gutierrez et al. 2017).

Design prescribed fires and manage natural ignitions to leave some unburned patches, especially in larger burn units, to provide diversity and refugia for owl prey. Unburned areas should generally be in areas protected by topography; for example, stream confluences, lower slopes, benches, and headwalls (Camp et al 1997, Mallek et al. 2013, Meyer et al. 2007, Roberts et al. 2015)

To conserve key habitat, such as very large trees or snags, consider pre-treatment activities, managing a fire's progression, or both. An example of pre-treatment is raking fuels away from boles of known spotted owl nests and roosts prior to burning (see page 24 for more information).

To manage natural ignitions, use relative risk inputs in Wildland Fire Decision Support System for duration of burn season to assess risks to owl habitat in the short and long term. Examples of relative risk inputs are flame length, burning index, and energy release components. Manage natural ignitions where appropriate to restore fire as a natural process, produce fire effects in the natural range of variation, and protect owl habitat elements that are in the natural range of variation.

Energy release component guidelines will be based on both current fuel characteristics and restoration needs. For example, when fuels are largely restored, one may use energy release component trends near the 20-year average to get an appropriate mix of fire severities, considering the effects of warming climate. In areas that have not experienced fire over a long period, one should consider using lower-than-average energy release component values for restoration opportunities.

The seasonal timing of prescribed burns should vary to help meet restoration goals for areas of burn severities, gap sizes, species composition, and habitat retention. In highly departed

forest ecosystems with high fuel loads and high fire hazard, burning when fuel moisture is high (for example, during the early season) may mimic the effects of frequent, low-intensity fire regimes (Knapp et al. 2009). Where fuel conditions are restored, other risks are low, or both, the natural range of variation in seasonal timing of prescribed burns might be used as a guide. These burns would typically take place mid to late summer to early fall, with some instances of early burning in dry years.

For spring burns during spotted owl nesting season (March through July), plan prescribed burns so the smoke disperses away from nests. This will prevent caustic levels of carbon monoxide from accumulating in the nest. Plan prescribed burns so smoke moves off the ground at night to keep extensive, stagnant patches of smoke from interfering with owl foraging.

Prior to, and during, fire season, perform risk assessments to assess thresholds under which natural ignitions may be managed to burn within the natural range of variation. When naturally ignited fires burn under such thresholds, strive to manage them to keep burning intensities and patterns consistent with the natural range of variation. It is not necessary to generate high-severity fire in forested high quality owl habitat.

Manage natural disturbances other than fire so they are in the natural range of variation. Restoring vegetation pattern, structure, and composition across large portions of the landscape should create disturbance dynamics in the natural range of variation; however, changing conditions on the landscape may require swift and adaptive response.

Where vegetation management alone will not move insect disturbance toward the natural range of variation, consider the following to protect high-value trees for owls (e.g. known nest/roost trees and very large trees):

- Use beetle anti-aggregate pheromones to protect high-value trees
- Use preventive insecticides to protect high-value trees from bark beetle attacks
- Restore tree species disproportionately affected by outbreaks; for example, sugar pine

In drier areas, reduce stand densities to reduce the probability of drought-related mortality (Young et al. 2017). Prioritize treatments in areas of high value, in areas with high climate stress indices, or both. Young and other suggest (2017) prioritizing based on areas where the forest deficit-competition index is greater than 0.8.

7. **Facilitate development of landscape conditions towards the natural range of variation (or future range of variation) after a natural disturbance.** This will entail active restoration where conditions are trending away from the natural range of variation. This will entail support of natural processes where conditions are trending towards the natural range of variation. Restoring disturbed landscapes will benefit the owl by creating and maintaining forest conditions similar to those in which the owl evolved and that are likely to persist in the future. Restoring disturbed landscapes regimes will create a dynamic and diverse mix of nesting, roosting, and foraging habitat and diverse and abundant habitat for prey species (objectives 3A, 3B, 3C, 3D, 3E).

   When considering whether active restoration is needed in an area affected by a natural disturbance, evaluate the landscape condition to determine if it is in the natural range of variation (including areas outside of the disturbance perimeter) in terms of vegetation pattern, seral stage diversity, stand structure, species composition, and understory conditions.

Consider the landscape context in which the disturbed area is situated. The need for an active response should be based on overall conditions at the neighborhood scale and landscape scale not the stand or patch scale.

When a post-disturbance landscape is in the natural range of variation and habitat development is expected to remain in that range or move toward the future range of variation, no active management or limited management may be warranted. In such instances, only engage in management actions intended to keep vegetation pattern, structure, composition, and function on the desired trajectory. The following management may be appropriate on post-disturbance landscapes in the natural range of variation:

- Prescribed fire treatments to maintain the natural fire regime, fuel loading, and fuel continuity for the area.
- Vegetation monitoring to help to determine succession in post-fire environments under warming climate conditions.
- Restoration treatments to restore natural fire and other disturbance regimes and promote beneficial fire effects in the future (for example, fire anchor points). These treatments would be part of a larger landscape-scale planning effort.

When a post-disturbance landscape and habitat development are outside the natural range of variation, active restoration may be warranted to move conditions toward the natural or future range of variation and create long-term resilience. Treatments should develop vegetation pattern, structure, composition, and processes in the natural range of variation based on site conditions and the landscape in which the disturbed area occurs. Restoration and resilience should generally be guided by the recommendations elsewhere in this conservation measures section. The following additional recommendations should also be considered:

- Design and locate activities to preserve the best remaining patches of owl nesting, roosting, and foraging habitat inside and outside protected activity centers, while simultaneously planning for the desired trajectory of the landscape as a whole.
- Develop fuel treatments to minimize the risk of subsequent fires burning outside the natural range of variation and to facilitate future use of prescribed fire and wildfire managed for resource objectives. For example:
    - Use stand- and neighborhood-scale mechanical treatments to establish spatial fire anchor points (areas with low fuel levels from which prescribed and managed fire can be strategically expanded on the landscape) (North et al. 2015; Thompson et al. 2007).
    - Retain large logs consistent with natural range of variation values. Fine fuel values should generally be less than 5 tons per acre.
    - After mechanical treatments to remove dead and dying trees, remove slash from the site to prevent short-term increases in surface fuel loading (Johnson et al. 2013) Examples of slash removal are post-harvest piling, burning, or a combination of both.
- Retain individual snags and patches of snags, with a preference for snags larger than 45 inches in diameter at breast height. Leaving a clump of snags or trees around large snags may help protect them from wind. Retain some patches of snags where the size, snag density, and condition of the patches are in the natural range of variation.

- Within treated areas, retain patches of severely burned forest. Patches should make up less than 15 percent of the landscape. Patch sizes should generally be a quarter of an acre to 10 acres. There should be approximately 140 snags per acre, averaged at the mid-scale. Retention areas for severely burned stands should be in areas more likely to have experienced severe fire effects under the natural range of variation, such as upper portions of south-facing slopes (Collins and Skinner 2014).
- Within treated areas, retain patches of trees killed by bark beetles. Patches should make up less than 15 percent of the landscape (Fettig 2012) and should be in small clumps of 2 to 4 trees (Lyderson et al. 2013).
- Consider reforestation when natural regeneration at the stand level is not likely to provide the abundance, distribution, and species composition of seedlings in the natural range of variation (within the succeeding decades). Treatments should create future stands with diverse structure and appropriate densities in the natural range of variation.
    - Plant seedlings at densities and spatial configurations consistent with early reintroduction of fire and resilience goals. Select favorable sites based on soils, topography, and projected changes in climate and climatic water deficit. Where feasible, use fire to maintain low fuel conditions as stands develop (York et al. 2014). Low fuel conditions, minimal competition, and early reintroduction of low intensity fire minimize the risk of substantial mortality from moderate fire (Skinner and Weatherspoon 1996, York et al. 2014).
    - Where sugar pine would have been present under the natural range of variation or are likely to be present under the future range of variation, plant a mixture of seedling genotypes, including blister-rust-resistant individuals.

Natural disturbances may sometimes be so extreme and post-disturbance condition so far outside the natural range of variation that restoration may take centuries. An example is a high-severity fire which burns contiguous blocks of thousands or tens of thousands of acres across entire watersheds. The goal for such areas should be to increase resilience and move toward the natural range of variation (considering projected future conditions), but restoration may take many iterations of management intervention and the areas may be outside the natural range of variation for decades, if not centuries. In such instances, the specific recommendations in this conservation strategy will likely need to be adjusted by local decision-makers based on the unique conditions associated with extreme disturbances.

8. **Restore Sierra Nevada forests in the California spotted owl's range**. Active forest management will be required at an urgent pace and massive scale to avoid more acreage moving further outside the natural range of variation (Stephens et al. 2016a). Expeditious forest restoration will benefit the spotted owl by moving landscapes closer to the conditions in which the spotted owl evolved and that are likely to persist in the future. Restoration will also reduce risks posed to owl habitat from disturbances outside the natural range of variation (objectives 2B, 2E, 3A, 3B, 3C, 3D, 3E). This will require use of all available tools: mechanical and fire treatment and regulatory and policy mechanisms like memorandums of understanding, collaborations, and partnerships.

   At the Sierra Nevada scale, actively manage or burn approximately 184,000 to 488,000 acres of National Forest System land annually. Managing at this scale will approach the acreage burned annually under a natural fire regime (North et al. 2012). However, management levels significantly above and beyond the 184,000- to 488,000-acre natural disturbance level should

be considered in the near future to address the backlog of nearly 3 million acres of fire suppressed land that currently exists (North et al. 2012).

Achieving complete restoration to the natural range of variation, and eventually the future range of variation, may not be possible given constraints. When restoration and treatment can be strategically placed throughout the landscape, treating at least 20 percent of the landscape can consistently reduce modeled fire size and behavior (Collins and Skinner 2014). Significantly higher levels of restoration and treatment would be needed if optimization of treatment patterns is limited by land management constraints (Collins and Skinner 2014). Increased effectiveness in influencing landscape function and disturbance can be achieved by restoring and/or treating up to 40 percent of the area at the landscape scale (Lydersen et al. 2017), and even more treatment may be required under future climate regimes (Westerling et al. 2015). At a patch neighborhood scale, roughly 25 to 60 percent of the landscape may need to be treated to influence fire severity (Lydersen et al. 2017), whereas at a patch scale, even more treatment may be necessary to influence fire severity (50 to 75 percent at the scale of 500 acres; Lydersen et al. 2017).

Based on current conditions, a mix of mechanical treatments, prescribed fire, and managed fire will be needed to move landscapes toward the natural range of variation while minimizing the risk of severe disturbances that impede landscape restoration (Stephens et al. 2016a; Collins et al. 2017). Reintroduction of fire as an ecosystem process should be a goal in restoration projects (Stephens et al. 2016a).

In stands with high departure from the natural range of variation, use mechanical treatments to reduce stand densities, restore forest structure, and reduce the risk of losing critical nesting and roosting habitat to fire or other disturbances. Mechanical treatments may also be needed in stands with low departure where it is difficult to implement prescribed fire without additional pretreatment. Pretreatment may be necessary to protect resource values, to increase the pace and scale of treatment for the surrounding landscape, or both. Follow mechanical treatments with prescribed burning to improve treatment effectiveness and begin restoring a natural fire regime.

Take advantage of cross-boundary collaborations and partnerships, as well cooperative management endeavors, to implement restoration. Further, take advantage of restoration-aimed funding sources to increase scale and effectiveness of landscape restoration through collaborative focus on high-risk and high-need areas.

Strategy 3. Minimize Other Threats (Barred Owls, Disease, Rodenticides) (Goal 1)

1. **Implement monitoring and control studies for barred owls in the Sierra Nevada at the Ecoregion scale** (objective 1B)**.** The scientific literature has demonstrated that as barred owl numbers have increased within the northern spotted owl range, spotted owls are negatively impacted at multiple levels and populations have declined as a result. Given the impacts of barred owls on northern spotted owls, an interagency barred owl research and monitoring program, should be developed and implemented as soon as logistically and administratively possible while barred owls still occur at low densities in the Sierra Nevada. The California Department of Fish and Wildlife has convened a Barred Owl Science Team to inform the development and implementation of such studies, and regular interagency communication on the subject will be important.

Barred owls and sparred owls (spotted owl-barred owl hybrids) are currently concentrated in the northern Sierra Nevada, though recent limited observations in the southern Sierra Nevada have also occurred. While barred owl numbers are likely relatively low, they will continue to increase over time. A barred owl research/management program in the Sierra Nevada would further our scientific knowledge on barred owls, such as density/abundance, demographics and movement ecology. It may also include examination of feasible management measures at the local, regional or landscape level. A barred owl removal study will result in a better understanding of the impacts barred owls have on California spotted owls, and will likely inform the most effective management approach in the Sierra Nevada. When developing a removal study, spatial and temporal design should be considered (e.g., location and density of barred owls on the landscape, effective configuration and timing for removals). In addition, an outreach and communication program should be developed to foster public understanding, support and engagement in the need for a barred owl removal study. Development of effective strategies in relation to the barred owl will require developing and implementing surveys with a high probability of detecting and locating territorial individuals over large spatial scales. There is an urgent need to implement an effective study while barred owl population densities are low enough to provide the potential for a wide range of study results.

2. **Increase understanding of effects of disease and contaminants on California spotted owl fitness** (objective 1A).

   Little information exists on disease prevalence in spotted owl populations, and no information exists regarding the effects of disease on individual fitness or population viability (Gutierrez et al. 2017). There is no evidence West Nile virus has significantly impacted California spotted owl populations to date (Gutierrez et al. 2017), though it may pose a threat in the future.

   Rodenticides are an emerging threat to California spotted owls, though no information is available at this time to evaluate the magnitude and consequences of this threat (Gutierrez et al. 2017). High exposure rates were recently recorded in barred owls and northern spotted owls (Gutierrez et al. 2017; Thompson et al. 2017; Gabriel et al. 2018) and it is likely California spotted owls also have high exposure rates. More research is needed to assess exposure rates of California spotted owls, effects of exposure, and potential mitigation measures.

Strategy 4. Foster Climate Adaptation of California Spotted Owls and Their Habitat to Achieve Long-term Conservation (Goal 3)

For the California spotted owl, lower elevation sites (less than 4,500 feet) with warmer microclimates and more open canopy cover may be important, near-term (the next 40 years) refugia, as the owls there are most resilient to warming (Jones et al. 2016). Thus, increasing resilience and heterogeneity at lower elevation sites is a key near-term climate adaptation strategy. In the longer term (end of the century and beyond), high-elevation sites with higher canopy cover are more likely to become refugial sites for the owls (Jones et al. 2016). Increasing presence and resilience of large tree, closed canopy forests at higher elevations (more than 4,500 feet) is therefore an important aspect of developing future refugia for the species, and North and others (2017) recommend managing these potential refugia for cooler, moister forest types. Further, maintaining connectivity between lower elevation mid-century refugia and higher

elevation end-century refugia will become important to aid in species migration as refugial patterns shift upslope.

1. Proactively augment tree migration during reforestation efforts for the purpose of developing future California spotted owl habitat resilient under the future range of variation
2. Manage potential large tree higher-canopy cover refugia for cooler, moister forest types at higher elevations to promote sustainable California spotted owl habitat (North et al. 2017).

Section 8. Monitoring and Adaptive Management

Population and Habitat Monitoring

Monitoring is critical to increase understanding of rangewide and population-specific changes (U.S. Fish and Wildlife Service 2017). While the existing long-term demography studies have provided a wealth of information on California spotted owls, important knowledge gaps remain. In particular, California spotted owl distribution and population dynamics throughout the rest of their range, as well as viable population sizes and responses to regional scale stressors, remain largely unknown (U.S. Fish and Wildlife Service 2017). Further, trends in key spotted owl habitat, particularly in relation to biophysical conditions and management regimes, remain relatively unclear. The development and implementation of a rangewide monitoring program will help fill these knowledge gaps and answer important questions. Coordination of a monitoring program that reaches across agencies, land owners, habitat types, and different management regimes will be critical to informing an adaptive management context in the future. Information sharing and research and monitoring partnerships are already underway between the USDA Forest Service Pacific Southwest Region and agencies like the National Park Service and U.S. Fish and Wildlife Service, research institutions like universities and the Pacific Southwest Research Station, and landowners with significant proportions of the California spotted owl habitat. These partnerships and collaborations should be continued and expanded in the future to carry out effective monitoring programs.

Questions

1. **Is the population and distribution of California spotted owls likely declining, increasing, or stable?** What is the current occupancy across the range, particularly as related to protected activity centers and modeled suitable habitat? How is occupancy changing over time and space?
2. **How is California spotted owl habitat changing over time?** Is the number of large trees on the landscape increasing and is their distribution changing? Is the distribution of large-tree, high canopy cover habitat increasing in alignment with biophysical conditions that are likely to support that habitat? How are the number and locations of protected activity centers on the landscape changing over time?
3. **How are threats to the California spotted owls changing over time?** Are barred owl populations increasing in size, distribution, or both? Is the rate of change in barred owl populations constant, increasing, or decreasing? How are fire size and severity and overall area burned trending over time? If the distribution of owls is changing over time, is there a relationship to changes in habitat, disturbance, or management activities?

Objectives

1. Assess the current distribution of California spotted owls in the Sierra Nevada
2. Monitor changes in California spotted owl distribution and occupancy rates over time
3. Assess changes in amount and distribution of key owl habitat, including large trees and large and tall tree-high canopy cover habitat
4. Assess trends in stressors over time and effects of disturbance and restoration on California spotted owl
5. Identify and prioritize territories and protected activity centers for restoration
6. Monitor effects of barred owls (see barred owl monitoring section below)

Methods and information sources

Population

The Forest Service Pacific Southwest Region is partnering with the University of Wisconsin-Madison and the Pacific Southwest Research Station to develop a protocol for rangewide occupancy monitoring using autonomous acoustic recording units. Acoustic recording units are already being used to monitor the Northern spotted owl. Acoustic recording units would be used to passively record calls of spotted owls, barred owls, and other species. An acoustic recording unit array arranged in a sampling design matrix across the landscape would provide the data necessary to assess changes in the abundance and distribution of California spotted owls (and barred owls). While the precise sampling design matrix is in development, it would involve the deployment of a network of acoustic recording units randomly within each of two different strata – protected activity centers and suitable habitat outside protected activity centers. The total number of acoustic recording units deployed, and the number of units deployed per sample unit, will depend on the results of an initial pilot studies and power analyses being conducted in 2017 and 2018. The sampling scheme, when combined with habitat monitoring metrics (see section below), will provide a framework for understanding how environmental change, forest management and restoration, and changes in barred owl populations influence California spotted owl distribution and abundance. Survey protocols may be revised to incorporate acoustic-recording–unit-based surveys following pilot study results.

Habitat and Management

The Forest Service Pacific Southwest Region Remote Sensing Lab (RSL) is currently developing multiple mapping products that would allow for frequent monitoring of status and trends in California spotted owl habitat. Habitat monitoring should combine information from vegetation plots, remote sensing, and management activity databases to include the following metrics: status and trend in canopy cover and large trees; status and trend of spotted owl suitable habitat; and effects of disturbance and management on spotted owl habitat suitability. The Monitoring Trends in Burn Severity database, in combination with the Ecosystem Disturbance and Recovery Tracker (eDaRT), may be used to monitor fire trends and trends in other disturbances over time. Finally, the Forest Service Natural Resource Information System (NRIS) can be used to monitor trends in number and distribution of protected activity centers over time.

Monitoring Other Threats

Barred Owl

Joint barred and spotted owl surveys (see above) would indicate barred owl distribution, and if a barred owl study is implemented, would also indicate which barred owls remained in, or recolonized, areas they occupied during removals. Surveys would also indicate whether spotted owls returned after barred owls were removed. Multi-species occupancy models would provide a rigorous statistical approach for estimating joint occupancy and understanding how barred owls limit the distribution of spotted owls. As information from initial barred owl studies develops, inventory surveys and removals strategies could be developed and refined as part of an adaptive management program.

Disease and Contaminants

Information is needed to identify rodenticide exposure rates in California spotted owls, and to understand potential trends in these exposure rates (U.S. Fish and Wildlife Service 2017). Monitoring of exposure rates, as well as working with law enforcement partners to monitor the amount of rodenticides on the landscape, will both be important for long-term spotted owl conservation (U.S. Fish and Wildlife Service 2017).

Tree Mortality

As we do not yet know how recent extensive tree mortality will affect habitat selection by the California spotted owl, monitoring the species response will be critical to informing conservation (U.S. Fish and Wildlife Service 2017). In addition, monitoring owl response to management actions that both respond to current mortality and prevent future mortality, represents an important component of adaptive management for the species in a changing climate.

Adaptive Management

Conservation measures, as outlined in this Strategy, should be modified and updated as information and conditions change through time. A well-maintained feedback loop between science and implementation is a key component to the success of this Strategy, and will require, at a minimum: novel and perhaps experimental management design, taking advantage of actions across different land ownerships and management objectives; post-implementation monitoring of populations and habitats following, in particular, novel or model management at large scales; and clear and timely communication across organizations and disciplines throughout the process. Monitoring of habitat, population, and management outcomes across different habitat types and management regimes (as described above) should be used to inform an adaptive management context. This strategy should be revisited and revised as the science and data continue to rapidly evolve.

Glossary

Active restoration: Prescribed burning, mechanical treatments, or both implemented to restore vegetation pattern, structure, composition, and processes to the natural range of variation.

Actual evapotranspiration: The amount of water that evaporates from the surface and is transpired by plants if the total amount of water is limited. It indicates potential tree growth and size.

Adaptive management: a management approach that involves exploring alternative ways to meet management objectives, predicting the outcomes of alternatives based on the current state of knowledge, implementing one or more of these alternatives, monitoring to learn about the impacts of management actions, and then using the results to update knowledge and adjust management actions.

Background mortality rate: expected death rate in the absence of extreme events

Basal area: average amount of an area (usually an acre) occupied by tree stems. It is defined as the total cross-sectional area of all stems in a stand measured at breast height. It is expressed as per unit of land area (typically square feet per acre).

Canopy closure: the percentage of the sky obscured by vegetation when viewed from a single point.

Canopy cover: the percentage of forest floor covered by the vertical projection of the tree crowns.

Climatic water deficit: a measure of the difference between potential and actual evapotranspiration. It is an indirect measure of how dry a site is.

Connectivity: the ecological conditions that exist at several spatial and temporal scales to provide landscape linkages to allow: the exchange of flow, sediments, and nutrients; the daily and seasonal movements of animals within home ranges; the dispersal and genetic interchange between populations; and the long distance range shifts of species, such as in response to climate change.

Core area: non-overlapping defended geographic areas in which a pair of territorial owls concentrates nesting, roosting, and foraging activities

Crown fire: a fire that spreads from treetop to treetop, remaining in the tree crowns.

Energy release component: a number related to the available energy per unit area within the flaming front at the head of a fire. Daily variations in ERC are due to changes in moisture content of the various fuels present, both live and dead.

Even-aged management: management that results in stands of trees composed of a single age class, for example clear-cutting

Fine fuel: 1 to 100 hour fuels (excludes 1000 hour fuels, or coarse woody debris)

Fire anchor point: areas with low fuel levels from which prescribed and managed fire can be strategically expanded on the landscape.

Fire-dependent ecosystem: an ecosystem where fire is essential and the vegetation is fire-prone and flammable. They are often called fire-adapted ecosystems.

Fire regime interval departure: a quantification of the difference between current and presettlement fire frequencies

Fire resistant vegetation: plants that do not readily ignite.

Fire return interval: the average number of years between two successive fires (Agee 1993).

Fire rotation: the length of time necessary for an equal-sized area to reburn (Agee 1993).

Fire severity: Degree of vegetation mortality. High severity is greater than 75 percent basal area mortality; moderate severity is 25-75% basal area mortality; low severity - <25% basal area mortality

Fire sensitive vegetation: plants more likely to be injured or killed by fire.

Fire weather: weather conditions that influence fire ignition, behavior, and suppression.

Foraging habitat: habitat that support spotted owl prey species, especially key prey species like woodrat or flying squirrel

Forest deficit-competition index: a single variable representing the combined effects of competition and mean annual climatic water deficit. It is interpreted as an indicator of how close a stand is to its climatic 'dry margin', given its basal area (Young et al. 2017).

Forest inventory and analysis: Forest Service program that provides information about America's forests. The program reports on status and trends in forest area and location; in the species, size, and health of trees; in total tree growth, mortality, and removals by harvest; in wood production and utilization rates by various products; and in forest land ownership.

Forest seral-stage: The developmental phase of a forest stand with characteristic structure and plant species composition.

Frequent-fire forests: forests that burned more frequently in the past. The frequent fire regimes typically result in primarily low and moderate severity burned areas with smaller proportions of high-severity patches.

Fully stocked: sites with a stocking value of 60 to less than 100. Indicates the extent to which a site is occupied by live trees and resulting competition for resources.

Future range of variation: f the estimated range of some ecological condition or process that may occur in the future and is deemed especially relevant when the effects of stressors like climate change, invasive species, and human influence are high and likely to move the system away from the natural range of variation.

Genotype: the entire set of genes in a cell, an organism, or an individual.

Hand treatments: using chainsaws to achieve desired structure, composition, or pattern in an area

Habitat elements: components of the ecosystem that spotted owls use as habitat. Key habitat elements are those ecosystem components, like large trees, that are preferentially selected for by spotted owls and are highly influential in occupancy and/or demographic rates.

High severity fire: fire that has resulted in greater than 75 percent basal area mortality

Historic range: range of spotted owls prior to European settlement

Home range: the area used by an individual to meet its life-history requirements. Typically includes all nesting, roosting, foraging, and territorial activities.

Ingrowth: the volume of new trees growing into the minimum measurable size class during the measurement period.

Ladder fuel: live or dead vegetation that allows a fire to climb up from the forest floor into the tree canopy

Legacy trees: trees that are large, old, and/or otherwise confer special value as wildlife habitat

Limited operating periods: restricts when forest operations occur to prevent or minimize disturbance to California spotted owls during the breeding, nesting, and fledgling periods.

Low severity fire: Fire that results in less than 25 percent basal area mortality

Mature forests:

Mechanical treatment: refers to machine-based fuels reduction and tree harvest (that is, use of ground-based heavy equipment such as feller-bunchers and skidders). It does not include hand thinning with chainsaws.

Metapopulation: group of populations that are separated by space but consist of the same species.

Moderate severity fire: fire that results in 25 – 75 percent basal area mortality

Mortality factor: cause (either direct or indirect) of death of an individual or multiple owls

Natural disturbance regime: disturbance regime under which an ecosystem or species evolved, prior to recent (post European settlement) management interventions, such as fire suppression

Natural range of variation: is the variation of ecological characteristics and processes over scales of time and space that are appropriate for a given management application. In contrast to the generality of historical ecology, the natural range of variation concept focuses on a distilled subset of past ecological knowledge developed for use by resource managers; it represents an explicit effort to incorporate a past perspective into management and conservation decisions. The pre-European influenced reference period considered should be sufficiently long, often several centuries, to include the full range of variation produced by dominant natural disturbance regimes such as fire and flooding, and should also include short-term variation and cycles in climate. The natural range of variation is a tool for assessing the ecological integrity and does not necessarily constitute a management target or desired condition. The natural range of variation can help

identify key structural, functional, compositional, and connectivity characteristics, for which plan components may be important for either maintenance or restoration of such ecological conditions.

Occupancy: stable (not transient) presence of at least one individual in a given area

Patch refers to a relatively homogeneous area that differs from its surroundings. Patches are the basic unit of the landscape that change and fluctuate. Patches have a definite shape and spatial configuration, and can be described compositionally by internal variables such as number of trees, number of tree species, age of trees, height of trees, or other similar measurements.

Population stability: probability of a population returning quickly to a previous state, or not going extinct

Probability of detection: the probability that an owl will be detected in an area, given that it is there

Productivity: Forest site productivity is the production that can be realized at a certain site with a given genotype and a specified management regime. Spotted owl productivity is the owl reproductive rate.

Protected activity center: 300 acres (121 hectares) of the best available, contiguous habitat around a nest or roost. Protected activity centers encompass habitat that is most likely essential for nesting and roosting but not for foraging or territorial defense. The habitat has a closed canopy (at least 60 percent canopy cover) with at least two layers of tree canopy and many large trees and snags.

Quadratic mean diameter: a measure of central tendency of tree size, which is considered more appropriate than arithmetic mean for characterizing the group of trees which have been measured.

Resilience: the ability of a population or ecosystem to recover quickly and/or maintain function after a perturbation

Shaded fuel break: areas with lower surface fuel loads, higher canopy base height, and often reduced canopy bulk density in comparison to the adjacent forest. Sufficient forest canopy is retained such that surface fuel is shaded and exhibits slightly higher fuel moisture content and lower eye-level wind speed than open areas with no canopy cover.

Sierra Nevada Ecosystem Project: a scientific review of the remaining old growth in the national forests of the Sierra Nevada in California and a study of the entire Sierra Nevada ecosystem by an independent panel of scientists with expertise in diverse areas.

Snag: a standing, dead or dying tree, often missing a top or most of the smaller branches.

Sparred owl: a hybrid of a barred owl and spotted owl.

Stand: a contiguous group of trees sufficiently uniform in age class distribution, composition, and structure growing on a site of sufficiently uniform quality to be a distinguishable unit (such as mixed, pure, even-aged, and uneven-aged stands).

Stand density index: a measure of the stocking of a stand of trees based on the number of trees per unit area and diameter at breast height of the tree of average basal area.

Stem density: the number of trees over a given area

Stomata: a tiny opening in the epidermis of a plant, through which gases and water vapor pass.

Strategically placed landscape treatments: Patches of fuel treatments placed throughout a fireshed to slow or redirect fire. The pattern of placement is determined through fireshed assessments and designed to eliminate continuous pathways of untreated fuel. The goals are to keep fire on the ground, slow it down, and reduce its intensity so it can be modified across large landscapes. (Brown 2009)
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1075&context=jfspbriefs

Suitable habitat: an area in which a species can or does occur.

Surface fuel: Needles, leaves, grass, forbs, dead and down branches and boles, stumps, shrubs, and short trees

Territory: the area in a home range that is defended by the resident pair of owls from members of the same species.

Tipping point: the point at which a series of small changes or incidents becomes significant enough to cause a larger, more important change.

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