Chapter 7: Threats to the Viability of California Spotted Owls

John J. Keane[1]

Introduction

The California spotted owl (Strix occidentalis occidentalis) is a species of conservation concern owing to threats to its habitat and populations. Verner et al. (1992) first assessed the status of the California spotted owl "The California Spotted Owl: A technical Assessment of it's current status" (CASPO) and identified four factors as either threats or potential threats to the viability of California spotted owl populations: (1) timber harvest and forest management, (2) wildfire, (3) development of gaps in owl distribution across the Sierra Nevada, and (4) human population growth and development. Since the publication of CASPO, other factors have emerged as threats to California spotted owl population viability: (1) the invasion of the barred owl (*Strix varia*) into the Sierra Nevada, (2) climate change that could affect owls and their habitat, (3) the invasion of West Nile virus in the owl's range, (4) the potential impact to owls from secondary ingestion of rodenticides used to kill rodents that eat marijuana, *Cannabis* sp., and (5) reduction in genetic diversity. In this chapter, I review threats identified in CASPO and emerging threats to California spotted owls in the Sierra Nevada that have arisen since CASPO. I have relied on key findings from peer-reviewed literature of forest ecology and management and California spotted owl ecology.

Evaluation of Threats Identified in CASPO

Forest Management

Logging and fire suppression were identified in CASPO as primary threats to California spotted owls and their habitat in the Sierra Nevada (McKelvey and Johnston 1992, McKelvey and Weatherspoon 1992, Weatherspoon et al. 1992, chapter 5). Key uncertainties were (1) whether critical habitat elements (old, large-diameter trees and associated large downed logs) would be maintained and perpetuated under current and proposed even-aged silvicultural prescriptions; and (2) whether dense, high canopy cover stands important to owls could be maintained given increasing risk of high-severity fire owing to historical fire suppression (chapter 5). In general, both public and private lands were managed similarly prior to CASPO (McKelvey and Johnston 1992). McKelvey and Weatherspoon (1992) recommended development,

[1] **John J. Keane** is a research wildlife ecologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1731 Research Park Dr., Davis, CA 95618.

adaptive monitoring, and experimental testing of forest management approaches that would move forest structure and composition toward a heterogeneous condition that likely persisted under the area's natural fire regime and to evaluate the effects of these approaches on California spotted owls and their habitat.

Following adoption of CASPO guidelines, forest management on national forests diverged from private land management. Overall, 83.4 percent of the timber volume harvested from 1994 through 2013 came from private lands (chapter 5). During this time, group selection, shelterwood removal, and clearcutting were dominant on private land. In contrast, commercial thinning, salvage logging following wildfires, and hazard tree removal were dominant on national forest lands. About 73 to 80 percent of important California spotted owl habitat types occur on national forest lands in the Sierra Nevada (chapter 5). Differences in forest management among national forests, national parks, and private lands, along with variation in wildfire, have produced variable and complex landscapes across much of the Sierra Nevada. The scope and scale of cumulative effects is illustrated using case study demonstration areas. Figures 7-1 to 7-4 illustrate the complex landscape patterns generated by fire and forest management treatments within and surrounding four long-term demographic studies (Lassen, Eldorado, and Sierra National Forests and Sequoia and Kings Canyon National Parks) and within an area of mixed private-public ownership in the central Sierra Nevada.

Effects of forest management on California spotted owls—
Despite extensive research on spotted owls, the effect of forest management on owls is not well understood (USFWS 2011). Empirical field studies have been observational and correlative. Further, the complex mix of treatment types and wildfire across space and time impedes research efforts to isolate effects of specific treatment types because few owls receive the same type of treatment (figs. 7-1 to 7-4). Although experimental studies designed to understand the effects of logging have long been advocated (e.g., Gutiérrez 1985, McKelvey and Weatherspoon 1992, Noon and Franklin 2002, Verner et al. 1992), such studies have not been conducted, in part because they are technically, logistically, politically, and financially challenging. Such studies require organizational leadership, capacity, and institutional will to integrate multiple management objectives in the development and sustained testing of alternative land management strategies over large enough spatial and temporal scales to generate meaningful results (Gutiérrez et al. 2015). Although observational and correlative studies are of significant value, especially when replicated, they cannot produce strong inference (Romesburg 1981).

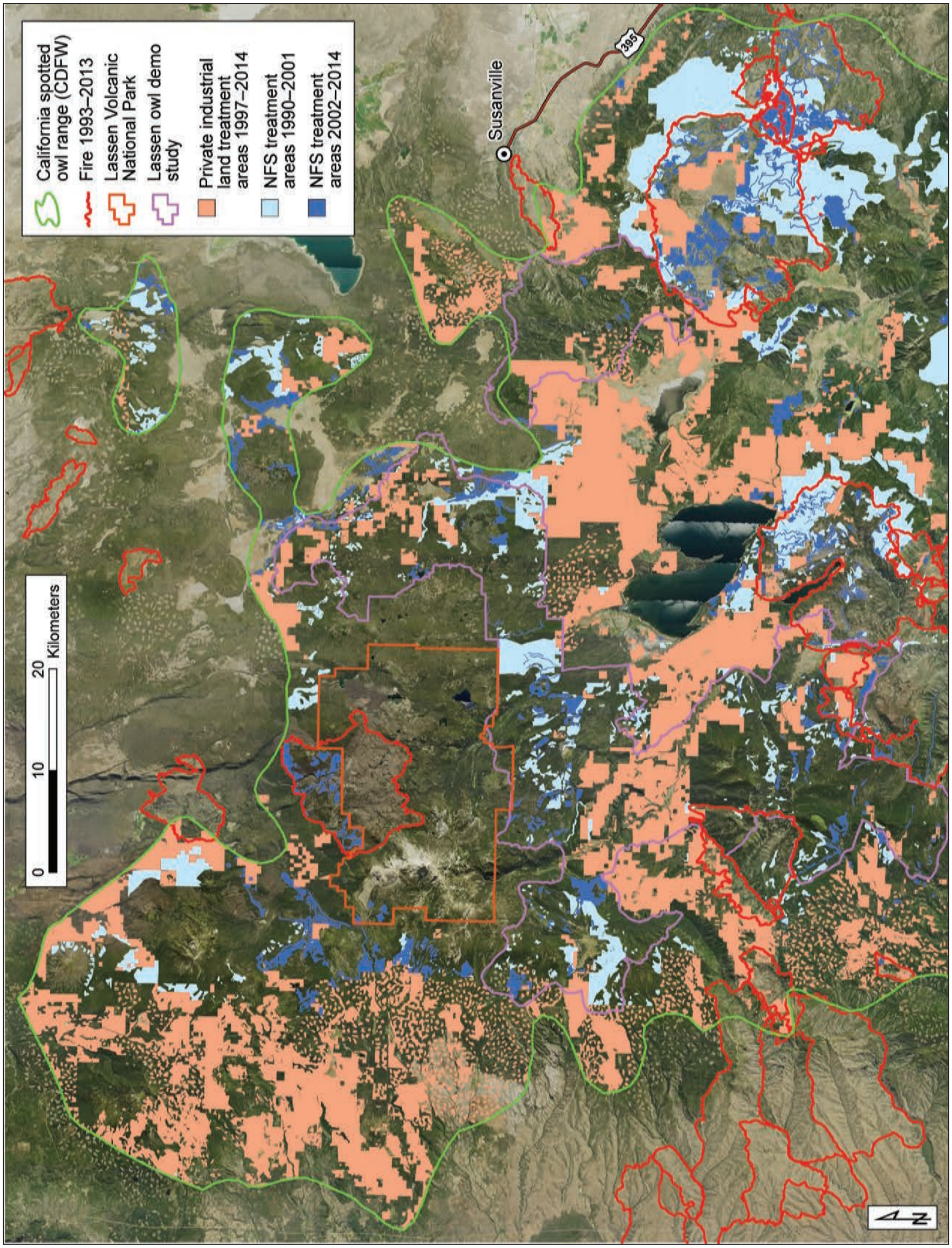

Figure 7-1—Distribution of forest management treatments on national forest and private industrial forest lands on the Plumas and Lassen National Forests in the region surrounding the long-term Lassen Demographic Study area during 1990–2014. CDFW = California Department of Fish and Wildlife, NFS = National Forest System. See text for further details.

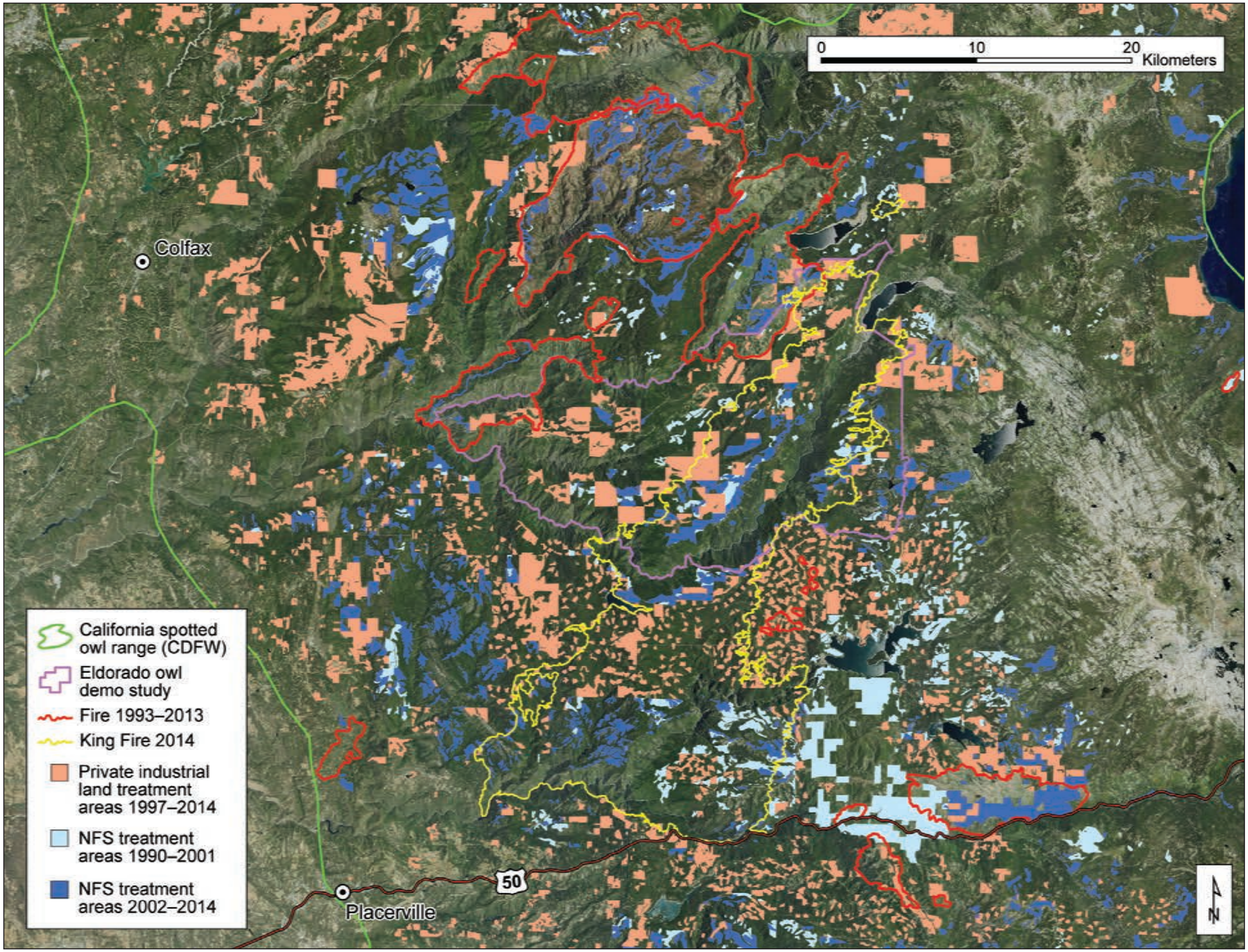

Figure 7-2—Distribution of forest management treatments on national forest and private industrial forest lands on the Eldorado National Forest in the region surrounding the long-term Eldorado Demographic Study area during 1990–2014. CDFW = California Department of Fish and Wildlife, NFS = National Forest System. See text for further details.

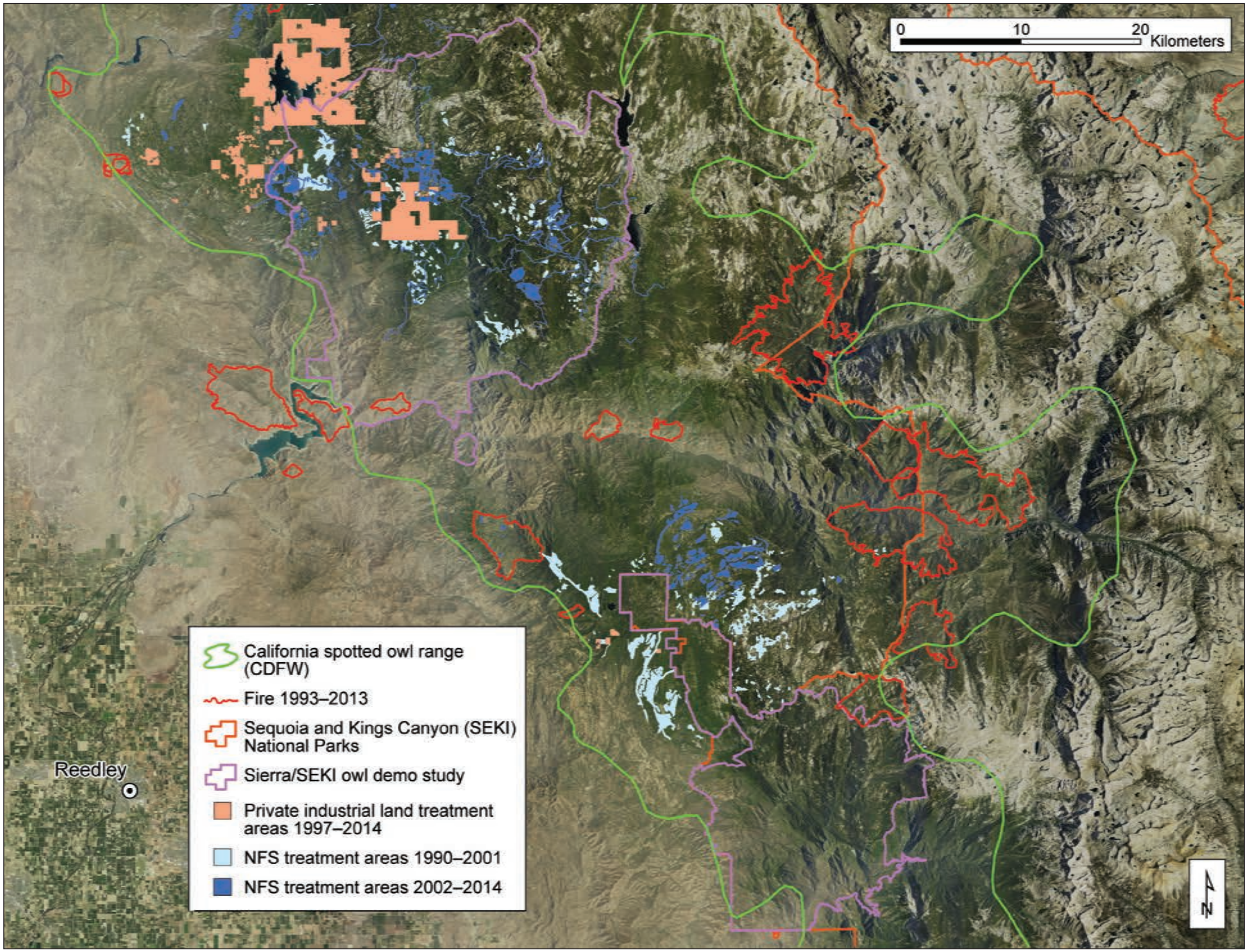

Figure 7-3—Distribution of forest management treatments on national norest and private industrial forest lands on the Sierra and Sequoia National Forests and Sequoia and Kings Canyon National Parks in the region surrounding the long-term Sierra and Sequoia-Kings Canyon Demographic Study during 1990–2014. CDFW = California Department of Fish and Wildlife, NFS = National Forest System.

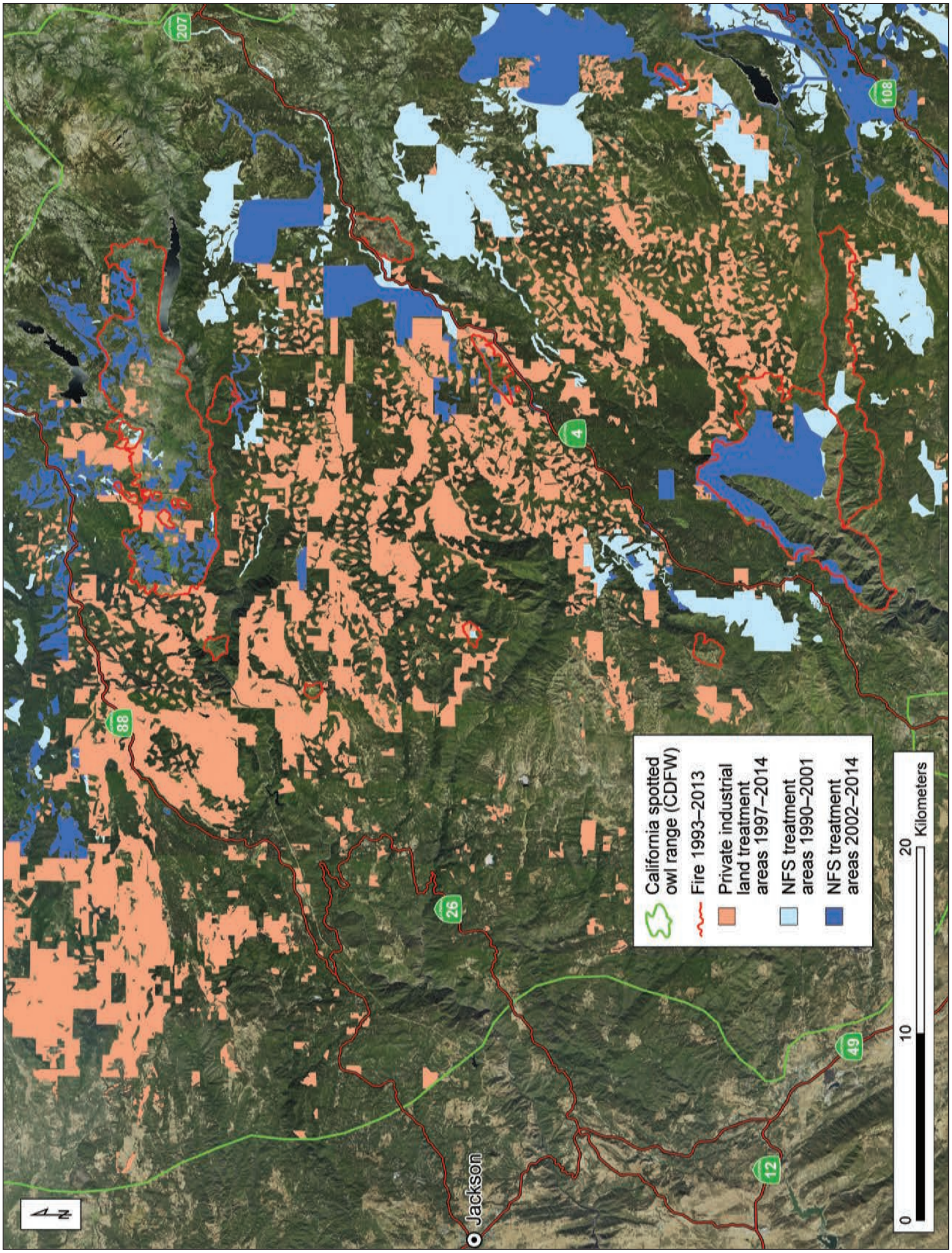

Figure 7-4—Distribution of forest management treatments on national forest and private industrial forest lands in a region of mixed public and private ownership on the Stanislaus and Eldorado National Forests during 1990–2014. CDFW = California Department of Fish and Wildlife, NFS = National Forest System.

Only three studies have explicitly addressed the effects of habitat change on California spotted owls at territory (Seamans and Gutiérrez 2007a, Tempel et al. 2014) and landscape spatial scales (Stephens et al. 2014). Seamans and Gutiérrez (2007a) concluded that California spotted owl territories with greater amounts of mature conifer forest defined as >70 percent canopy cover dominated by medium and large trees [30.4 to 60.9 cm (11.9 to 23.6 in) diameter at breast height (d.b.h.), and >60.9 cm >11.9 in d.b.h., respectively), had higher probabilities of being colonized and lower probability of being unoccupied relative to territories with lower amounts of mature conifer forest. Territories in which ≥20 ha (≥49.4 ac) of mature forest was altered experienced a 2.5 percent decline in territory occupancy probability. Breeding dispersal probability (the probability of territorial owls dispersing from an established site) did not change when ≥20 ha (≥49.4 ac) of habitat was altered in territories with >150 ha (>370.7 ac) of mature forest within a 400-ha (988.4-ac) circle centered on the site at the start of the study. However, an increase in breeding dispersal probability was observed at territories that started with <150 ha (<370.7 ac) of mature forest and experienced ≥2 ha (>49.4 ac) of habitat alteration. Thirty-eight of 66 territories in this study experienced habitat alteration, including fire at two territories and timber harvest at the other 36 territories. Timber harvest included clearcutting, thinning, and other prescriptions, but inferences were not made relative to a specific silviculture prescription.

Unlike earlier studies, Tempel et al. (2014) treated habitat change as dynamic over time and related annual patterns of change to owl survival, reproduction, population growth rate, and occupancy. Tempel et al. (2014) concluded that the amount of mature conifer forest >70 percent canopy cover; medium tree density (30.4 to 60.9 cm [11.9 to 23.6 in] d.b.h.) and large tree density (>60.9 cm [>23.6 in] d.b.h.) was the most important predictor associated with variation in demographic rates. This variable explained a large proportion of the variation in population growth rate and equilibrium occupancy, and was positively correlated with survival, equilibrium occupancy, and population growth, and negatively correlated with territory extinction probability. Further, medium-intensity treatments (such as thinning) were negatively correlated with reproduction and appeared to be related to reduced survival and territory occupancy when logging occurred in mature conifer forest that moved a class to a lower canopy cover state (e.g., canopy cover state changed from >70 percent cover to >40 to 70 percent). Of note, the probability of a territory going extinct was lower when the amount of mature conifer forest and high-intensity treatments (e.g., group selection, clearcut) increased and owl survival and population growth were positively related to the amount of habitat edge. Tempel et al. (2014) hypothesized that the juxtaposition of mature conifer forest and edge habitat with shrub/saplings may be important for increasing owl prey populations.

Only a single study has investigated the effects of landscape forest management on the owl (Stephens et al. 2014). They monitored owl territories annually after forest treatments within the 23 823-ha (58,867-ac) Meadow Valley Project Area (MVPA). Approximately 4161 ha (10,282 ac) of treatments were conducted during 2002–2008 (1784 ha [4,408 ac] of Defensible Fuels Profile Zone (DFPZ) treatments, 272 ha (672 ac) of group selections, 1440 ha (3,558 ac) of thinning, and 665 ha [1,643 ac] of prescribed fire). Seven to nine spotted owl sites were occupied in the MVPA before and during implementation of treatments during 2002–2007. However, the number of occupied sites declined to six from 2008 through 2010. In the third and fourth years of posttreatment, the number of occupied owl sites had declined to four (a 43 percent reduction in occupied owl sites in the MVPA). Thus, the landscape management strategy had negative short-term effects on spotted owls in the first 4 years after project completion; because there was a decline in occupancy of territories, owls responded to treatments by using larger areas. Further, there appeared to be a 2- to 3-year lag in spotted owl response time to the treatments. Although owls have been declining across the demographic study area over the past 25 years (Conner et al. 2013), the greatest magnitude of decline has been observed in the MVPA treatment landscape, suggesting a negative effect of the landscape treatment strategy (Stephens et al. 2014). Although, this study represents a quasi-experiment (observing behavior of owls after a treatment), the study is the first to monitor California spotted owl responses to a landscape-scale fuels treatment and logging strategy. It appears this landscape-scale management negatively affects spotted owls, which highlights the lack of robust adaptive management monitoring to assess the effects of fuels reduction and timber harvest on spotted owls.

Key findings from recent research on California spotted owl habitat associations—

There have been many studies of spotted owls since CASPO (chapters 2, 3, 4). These studies either confirm what was previously known, add detail (increased precision to estimates or nuances to early findings), or provide new insight (e.g., there is now strong evidence that California spotted owl populations are declining on areas of mixed U.S. Forest Service (USFS)–private land in the Sierra Nevada). The general patterns are that spotted owls are K-selected species having high survival and low annual reproductive output, that they select mature and old forest having high canopy cover (>60 to 70 percent) disproportionate to its availability, and that their occupancy is related to both the amount of this high canopy forest in their territories and the amount of forest that is lost to treatments. Moreover, the configuration of landscape types, amount, and distribution is apparently related to owl fitness (Dugger et al. 2005, Franklin et al. 2000, Tempel et al. 2014).

Current management—

Verner et al. (1992) identified habitat loss from forest management practices (logging and fire suppression), as a primary threat to California spotted owls. The CASPO strategy (1992) caused USFS forest management to diverge from private lands. The different forest management approaches by private and public land managers, along with wildfire and other disturbances, has resulted in spatially complex vegetation landscapes (see figs. 7-1 to 7-4 as examples of that complexity; see chapter 5 for details on available information on national forest and private lands treatment summaries).

Private industrial forests in the Sierra Nevada are managed using predominantly even-age silvicultural prescriptions (seed tree, shelterwood, and clearcut (chapter 5), although some private owners use uneven-age management. Because the owl is not federal or state listed, it does not receive special regulation on private land. Typically, a no-harvest buffer of 6 to 12 ha (15 to 30 ac) is established around active California spotted owl nest/activity centers (USFWS 2006). Previously known owl territories that are not currently occupied during project planning may receive no protection. McKelvey and Weatherspoon (1992) identified even-age management as a threat to owl habitat because critical habitat elements (old, large-diameter trees and associated large downed logs) and older forest stands would either decline or be lost eventually under this general system. There is no research on the specific effect of even-age management on owls and their habitat in the Sierra Nevada, but the northern spotted owl (*S. o. caurina*) was listed partially because of this type of silviculture. Recently, Sierra Pacific Industries (SPI) initiated research to assess the effects of even-age management on California spotted owls in the Sierra Nevada. Results from 2012 through 2014 indicate that owls are present across five study areas consisting of mixed SPI–Forest Service–other private owner lands, although further work is needed to assess habitat quality (chapter 4, Roberts et al.[2]). Alternatively, uneven-age forest management (e.g., hazard tree removal, selection harvest, thinning) remains a threat because of uncertainty regarding its effects on

[2] **Roberts, K.; Hall, W.E.; Shufelberger, A.J.; Reno, M.A.; Schroeder, M.M. 2015.** The occurrence and occupancy status of the California spotted owl on Sierra Pacific Industries' lands in the Sierra Nevada of California. 11 p. Unpublished document. On file with: Sierra Pacific Industries, 3950 Carson Rd., Camino, CA 96049.

owls and their habitat (e.g., loss of residual trees, reduction of canopy cover, simplification of forest structure).

After implementation of the CASPO guidelines (Verner et al. 1992) in the Sierra Nevada, national forests experienced a decline in the area logged annually with the majority of logging being commercial thinning and thinning from below to reduce fire risk (chapter 5). McKelvey and Weatherspoon (1992) and Weatherspoon and Skinner (1996) proposed that tree thinnings should incorporate heterogeneity into prescriptions; commercial thinning as implemented has tended to produce homogeneous conditions within treatment units. As typically implemented, thinning has emphasized reduction in surface and ladder fuels, maintaining trees ≥76 cm (≥30 in) d.b.h., and posttreatment canopy cover ≥40 percent. Usually the remaining overstory trees are regularly spaced with little forest floor and understory diversity and low horizontal and vertical heterogeneity in stand structure (Knapp et al. 2012). Recent evidence suggests that these types of thinning prescriptions may have negative effects on California spotted owls (Stephens et al. 2014, Tempel et al. 2014). In recent years, emphasis has refocused on silvicultural prescriptions that attempt to restore finer scale vertical and horizontal heterogeneity that would mimic predicted historical vegetation patterns (Knapp et al. 2012).

Fire suppression also has significantly affected forest structure with changes in vegetation patterns at the landscape scale, as well as increases in stand density and shade-tolerant species, reductions in forest understory vegetation diversity, and reductions of vertical and horizontal heterogeneity at the stand scale (e.g., Dolanc et al. 2014, Knapp et al. 2013; chapter 5). At the landscape-scale, fire suppression has contributed to increased homogeneity in vegetation with increases in the distribution, amount and continuity of younger to mid-aged stands across the landscape, which under a more active natural fire regime would have likely been characterized by a finer scale, heterogeneous vegetation landscape. Fire suppression also has contributed to increased fuel loads and ladder fuels, which has increased risk of stand-replacing fire effects (see chapter 5 for further details).

Forest management remains a threat to California spotted owl habitat and populations. Significant uncertainty persists about the effects of both public and private land management on California spotted owls and their habitat, and whether current vegetation trajectories on forest lands in the Sierra Nevada will support viable populations of owls because long-term monitoring of several owl populations across the Sierra Nevada document that owls are declining except on one study area on a national park (see chapter 4). The only consistent difference among these owl populations is forest management. Logging in national parks has been limited to very specific purposes such as roadside hazard tree removal or fuels hazard reduction around infrastructure, whereas logging has been more prevalent on private and national forests. Additionally, national parks make greater use of prescribed fire and managed wildfire. Other differences between national forest and national park study areas are discussed in Franklin et al. (2004) and Blakesley et al. (2010). The greatest population declines are occurring on the Lassen and Eldorado National Forests study areas (Conner et al. 2013, Tempel and Gutiérrez 2013). Although causative linkages have not been established, the higher rates of decline on these two study areas are coincident with the greater amount and extent of national forest and private lands treatments (see chapter 5 for details on types of treatments used on national forest and private lands since CASPO) within the study areas and surrounding landscapes relative to the Sierra National Forest study site (figs. 7-1 to 7-3). Recent research has indicated that dispersal dynamics and recruitment dynamics across larger landscapes and regions outside of study areas may have significant effects on owl population dynamics within fixed study areas (Schumaker et al. 2014, Tempel et al. 2014, Yakusic et al. 2014; chapter 4). Although there still remains uncertainty regarding the effects of USFS and private land management on California spotted owls and their habitat, the declining owl populations on the three national forest study areas coupled with two studies that show declines related to forest management indicate that forest management remains a threat to California spotted owls and their habitat throughout the Sierra Nevada.

Research on owl habitat associations at the territory-scale clearly demonstrate the importance of dense-canopy stands composed of medium-large trees for owl reproduction, survival, occupancy, and population trends. On the other hand, research documents that when foraging, owls will expand their habitat use to patches of younger forest having shrubs and along habitat edges between mature forest and other vegetation types (Franklin et al. 2000; Irwin et al. 2007, 2013; Williams et al. 2011). Studies relating owl demographic parameters to habitat patterns indicate the importance of territory-scale habitat configurations consisting of core amounts of complex-structured mature forest with intermediate amounts of habitat edges between forest and other vegetation types that produce heterogeneity and foraging habitat. However, neither the optimal mix of patches nor the optimal spatial configuration of vegetation is known. This pattern has also been reported for owls that occupy areas that experience mixed-severity fires including low amounts of stand-replacing fires (e.g., Bond et al. 2009). Thus, California spotted owls may respond favorably to forest management designed to produce fine-scale heterogeneity that benefits prey, such as woodrats, *Neotoma* sp. and *Peromyscus* sp. However, there is significant uncertainty about the amounts of edge and fine-scale heterogeneity that might be beneficial to owls. Little information is available to evaluate how edges created by different mechanisms (e.g., fire versus mechanical treatment) affect the value of habitat over both short and long timeframes. Nevertheless, although incomplete, available information is adequate to formulate hypotheses regarding amounts and patterns of habitat at territory and within-territory scales that could have been tested through adaptive management. This is a suggestion articulated both in CASPO and the Sierra Framework documents, but was not done.

Management in the Sierra Nevada is challenging because of vegetation and topographic variability owing to elevation and latitudinal gradients. This variation is further influenced by multiple ownerships, each of which is managing the land differently. Consequently, landscapes are diverse and subject to a mix of cumulative effects. Despite this reality, most studies center on either the territory-scale and within-territory-scale habitat associations. Less research has been conducted on landscape scales (Zabel et al. 2003). The spotted owl is a territorial species whose spatial organization appears to be structured according to an ideal despotic distribution (Franklin et al. 2000, Zimmerman et al. 2003). Understanding of the relationship between variation in landscape condition and population density and occupancy of owl territories is an important existing information gap to understand the status of owls in the Sierra Nevada, and to predict how density may be affected by changes in habitat proposed under alternative forest management scenarios.

Wildfire

At the time of the CASPO, little information existed about the response of spotted owls to wildfire (Verner et al. 1992). Wildfire was recognized as a potential threat to owl habitat because of increasing fuels loads resulting from fire suppression policies and the vulnerability of owl habitat to high-severity wildfire (McKelvey and Weatherspoon 1992, Weatherspoon et al. 1992).

Wildfire distribution and severity patterns in the Sierra Nevada: 1993–2013—Since CASPO, research has documented an increase in the amount of high-severity wildfire in the Sierra Nevada (Miller and Stafford 2012, Miller et al. 2009). Increases have occurred in both the amounts of high-severity fire and also the percentage of each fire burning at high severity for low- and mid-elevation conifer forest types. Loss of owl habitat to high-severity wildfire is an increasing threat to California spotted owls and their habitat, particularly in the context of climate change, high tree densities, high levels of tree mortality, and high forest fuels loads (Westerling et al. 2006; chapter 5).

Information on wildfire extent and severity patterns is available through the USFS Pacific Southwest Region Fire History database (Miller et al. 2009). About 445 154 ha (1.1 million ac) of conifer, hardwood, and mixed-conifer-hardwood vegetation types within the range of the California spotted owl in the Sierra Nevada experienced wildfire between 1993 and 2013 (table 7-1; figs. 7-5 to 7-8). About 35 612 ha (88,000 ac) of owl protected activity centers (PACs), representing about 15 percent of the total PACs acres, burned during 1993–2013. The PACs are a 121-ha (300-ac) management unit established to protect core nest/roost areas of owl territories (chapters 2 and 3). Recent research has documented the value of PACs as a management strategy (Berigan et al. 2012, Ganey et al. 2014). However, the effect of high-severity wildfire on PACs is of concern. Comparison of overall burn severity patterns in vegetation types that comprise PACs (conifer, hardwood, and mixed-conifer hardwood) across the Sierra Nevada to burn severity patterns in PACs indicates that the percentage of high-severity fire in PACs (28 percent) is similar to the percentage of high-severity fire across all burned acres (hectares) (26 percent). The percentage of moderate-severity fire is slightly higher in PACs (27 percent) versus overall (20 percent), while amounts of low-severity fire (PACs 36 percent, overall 40 percent), and unburned acres within fire perimeters (PACs 11 percent, overall 12 percent) are similar (table 7-1) (Keane, unpubl. data). These results indicate that PACs burned with similar proportions of high-severity fire compared to overall landscape fire severity patterns during 1993–2013. Similar to patterns throughout the Sierra Nevada (Miller et al. 2012), the number of PAC acres (hectares) experiencing fire, and high-severity fire has increased in recent years (fig. 7-9).

Table 7-1—Distribution of wildfire acres by burn severity class in protected activity centers (PACs) and across the range of the California spotted owl in the Sierra Nevada, 1993–2013[a]

	Burn severity class for acres within wildfire perimeters					
	Total acres	Burned acres	High	Moderate	Low	Unburned
			Percent			
Rangewide	7,466,532	1,092,814	26	27	36	11
PACs	557,165	88,021	28	20	40	12

[a] Percentages by burn severity class only include acres for conifer, hardwood, and mixed-conifer-hardwood vegetation type life forms that experienced wildfire. See text for further details.

Sources: Vegetation type life forms from California Fire and Resource Assessment Program 2006 30-m raster; fire severity from U.S. Forest Service (USFS) Pacific Southwest Region (R5) vegetation burn severity data; owl PACS from USFS R5 and Sierra Nevada National Forest management units; owl range from California Department of Fish and Wildlife.

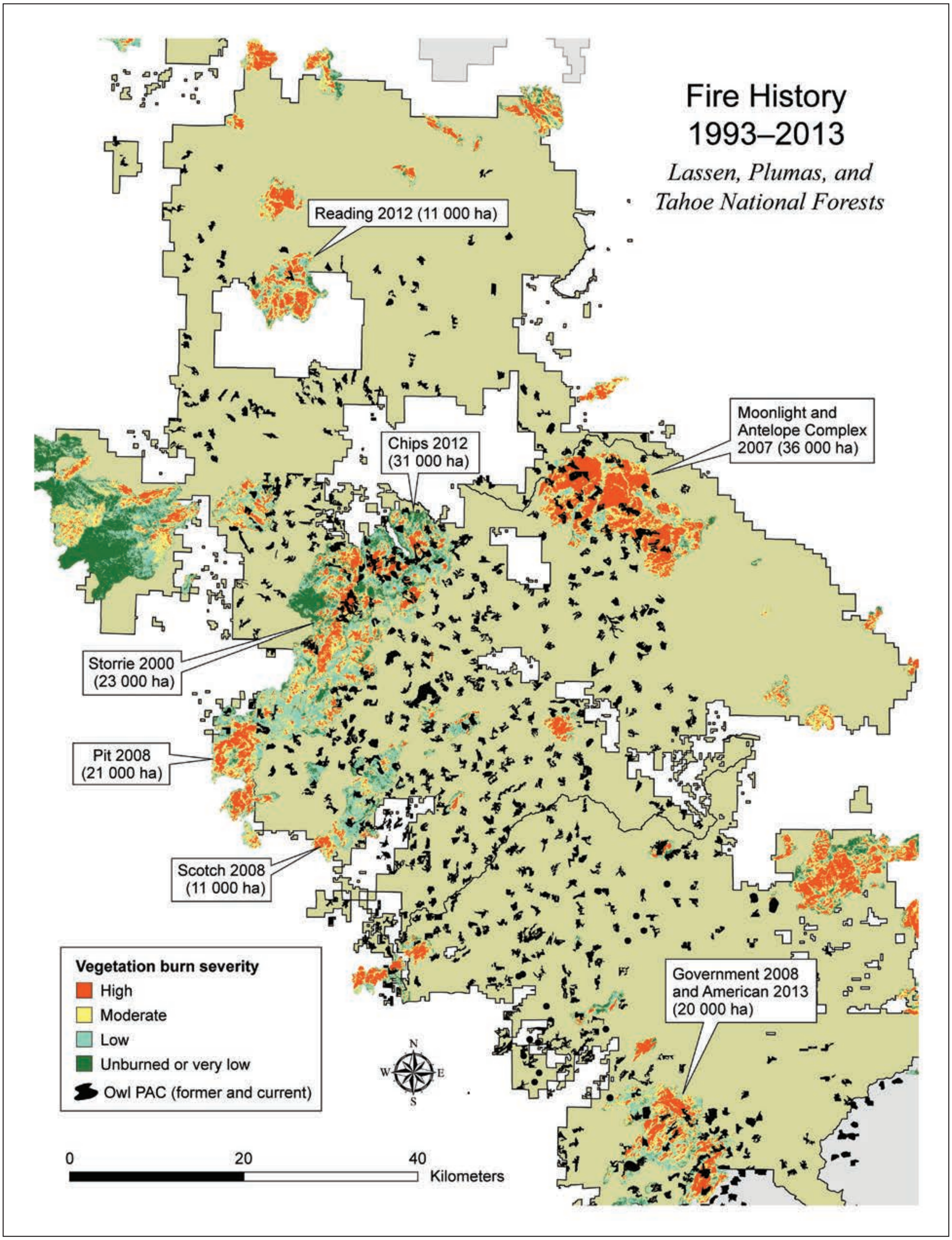

Figure 7-5—Distribution of wildfire hectares (ha) by burn severity class and California spotted owl protected activity centers (PACs) on the Plumas, Tahoe and Lassen National Forests in the northern Sierra Nevada and southern Cascades, 1993–2013.

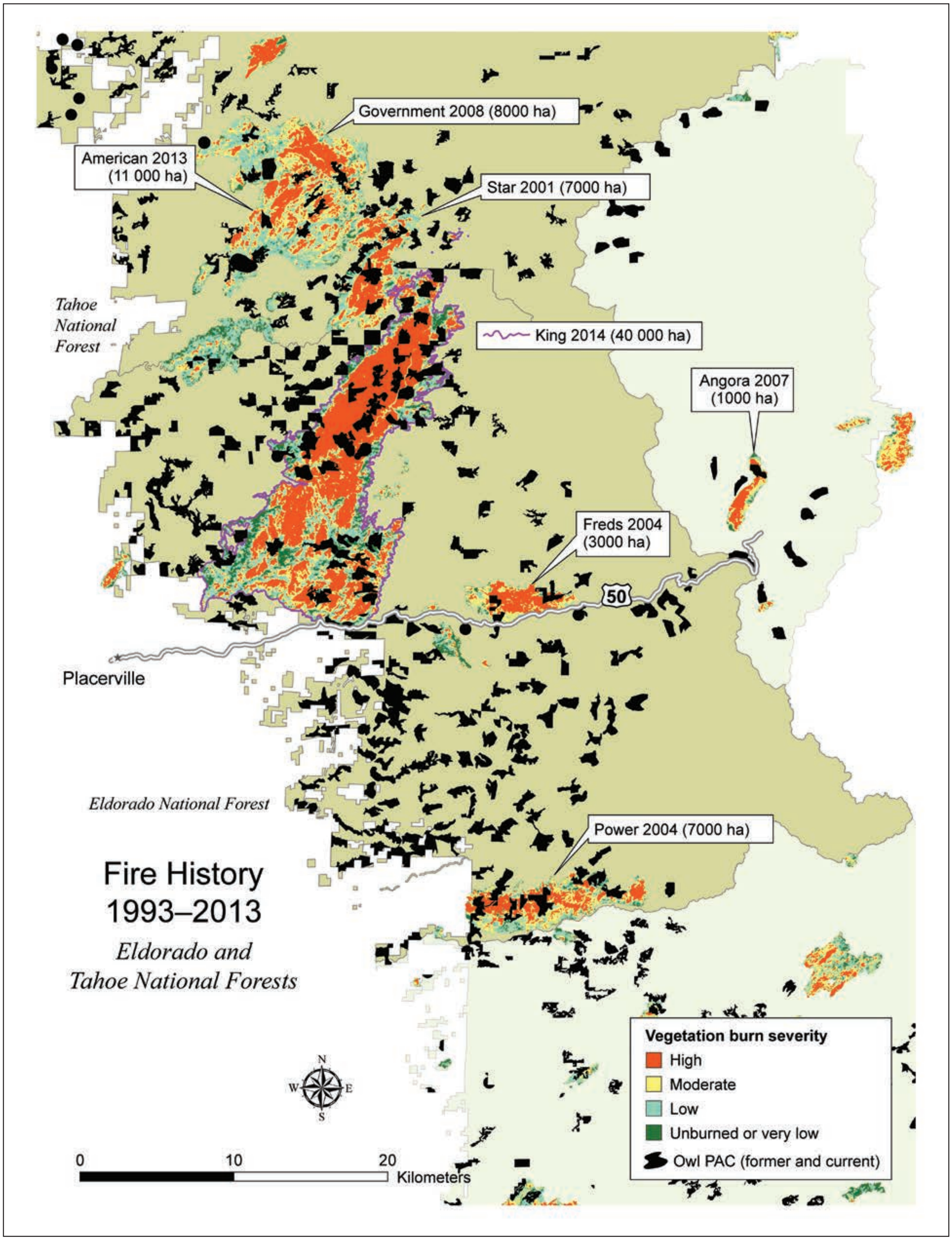

Figure 7-6—Distribution of wildfire acres (ac) by burn severity class and California spotted owl protected activity centers (PACs) on the Tahoe and Eldorado National Forests in the Sierra Nevada, 1993–2013. Includes the 2014 King Fire for comparison.

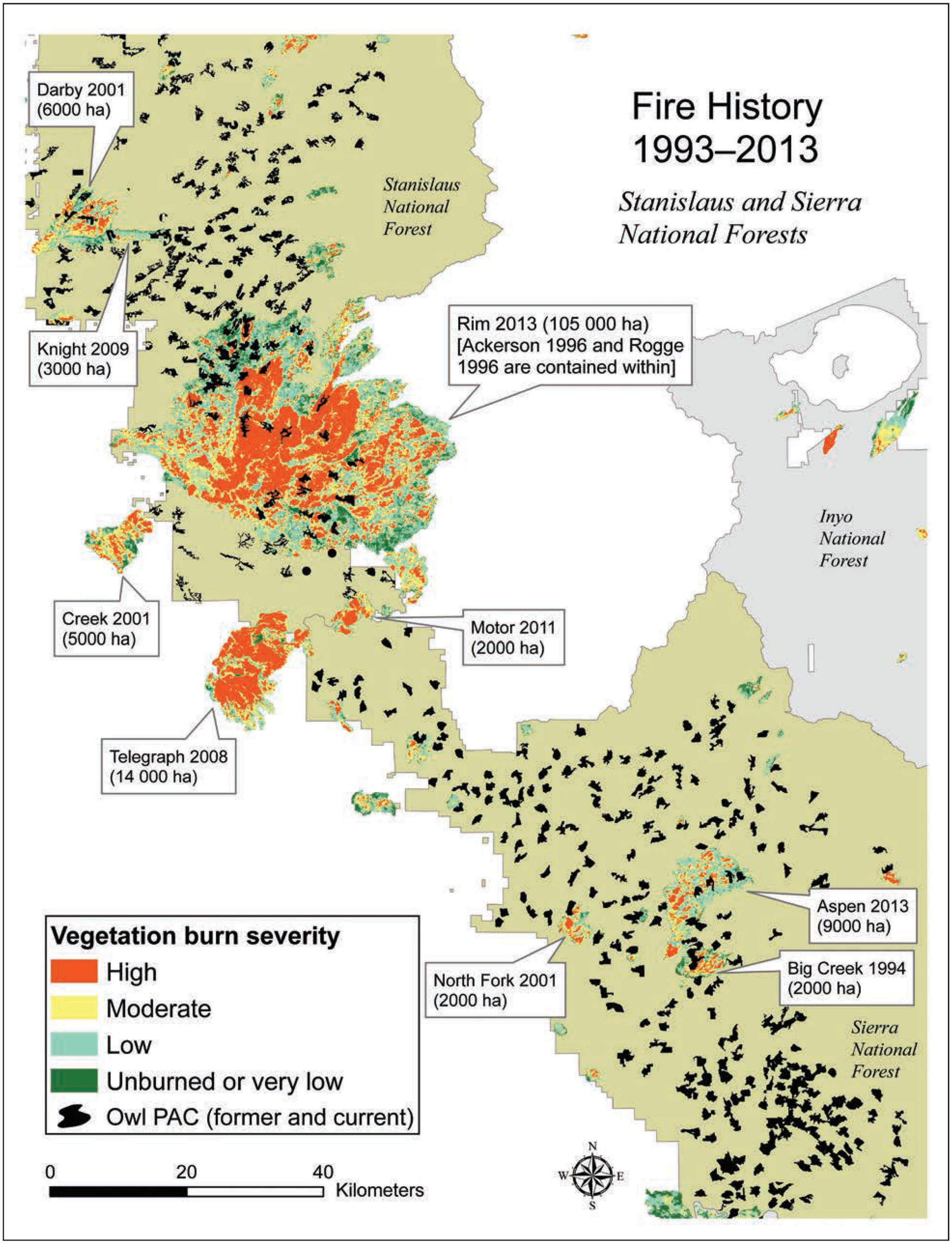

Figure 7-7—Distribution of wildfire hectares (ha) by burn severity class and California spotted owl protected activity centers (PACs) on the Stanislaus and Sierra National Forests in the Sierra Nevada, 1993–2013.

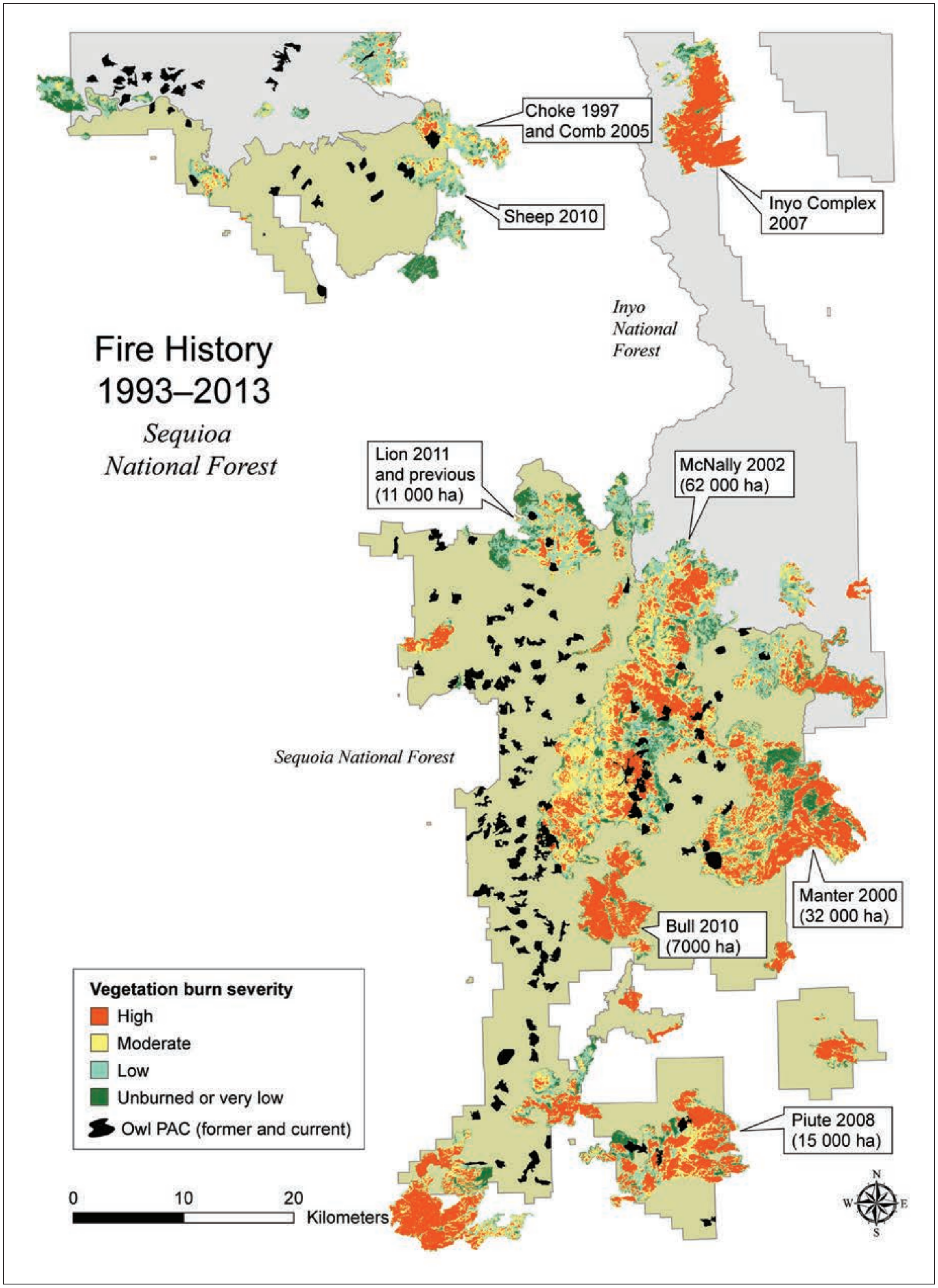

Figure 7-8—Distribution of wildfire hectares (ha) by burn severity class and California spotted owl protected activity centers (PACs) on the Sequoia National Forest in the Sierra Nevada, 1993–2013.

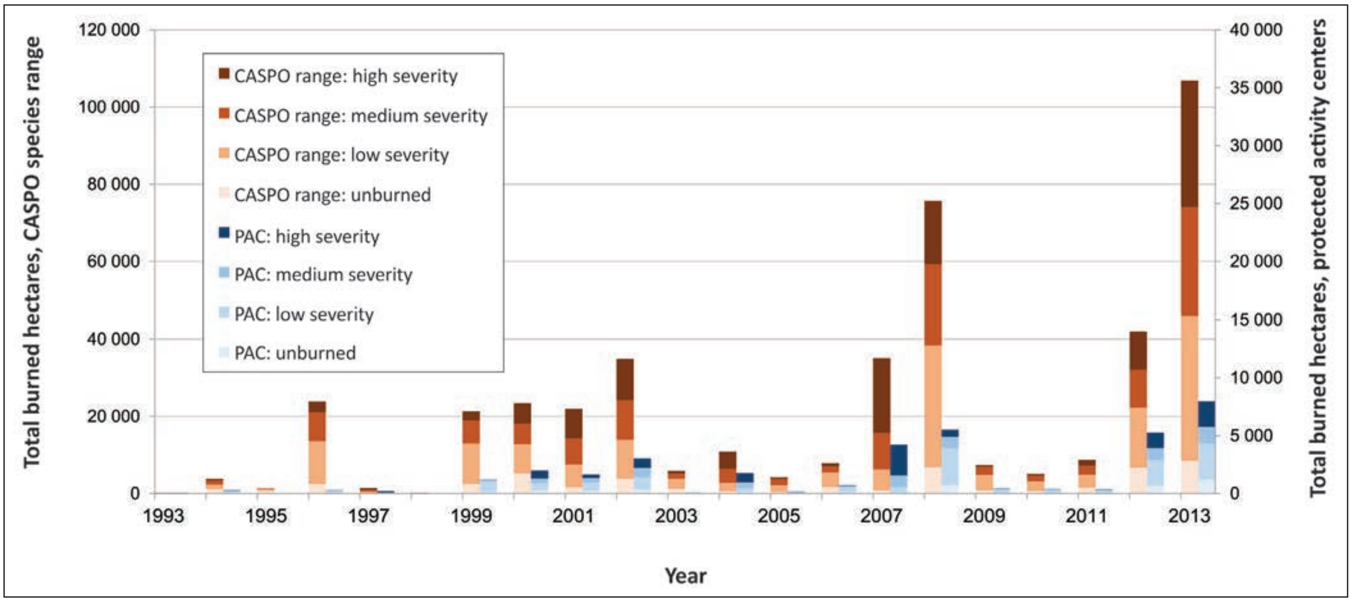

Figure 7-9—Distribution of wildfire hectares (ha) by burn severity class in protected activity center (PAC) and across the range of the California spotted owl by year, 1993–2013. Percentages by burn severity class for conifer, hardwood, and mixed-conifer-hardwood vegetation type life forms only include hactares (ha) within fire perimeters. See text for further details.

California spotted owl–wildfire associations—

Recent research indicates that California spotted owls persist at territories that experience low-moderate severity and mixed-severity (i.e., low-moderate fires with inclusions of high-severity) wildfire (see chapter 3) (Lee et al. 2012, Lee et al. 2013, Lee and Bond 2015, Roberts et al. 2011). Occupancy of sites by owls after fire appears to be a function of the amount of suitable habitat remaining postfire, the amount of suitable habitat burned at high severity, and whether postfire salvage logging is conducted. Available evidence indicates that postfire salvage logging may negatively affect postfire habitat suitability and confounds our understanding of owl response to fire (Lee et al. 2013). However, little is known about how salvage of commercially valuable trees affects owls. Further, no information is available to assess the response of owls to a range of postfire restoration management approaches that might emphasize primary objectives of ecological restoration rather than a sole focus on maximizing commercial value. Experiments are required to compare owl response at territories with and without salvage or postfire restoration management to disentangle the effects of treatments from the effects of high-severity fire, particularly at owls sites where >50 to 100 percent of suitable habitat burns at high severity (Lee et al. 2012, Lee 2013). Clark et al. (2013) concluded that northern spotted owl site occupancy declined in the short term (3 to 5 years) following fire, with postfire occupancy jointly influenced by prefire habitat conditions owing to management, fire severity patterns, and postfire salvage logging. Information on California spotted owl foraging in postfire landscapes is limited to one study conducted at four owl territories that experienced limited amounts of high-severity fire (mean = 9 percent, range 4 to 12 percent of owl home ranges) (Bond et al. 2009, 2013). Further research is needed on owl foraging habitat use across a broader gradient of territories to assess California spotted owl foraging habitat use patterns in postfire landscapes that experience greater total amounts, and increased patch sizes, of high-severity fire. While owls use the edges of high-severity fire patches, it is uncertain if they will use the interior of large patches of high-severity fire, such as the large patches observed in the 2013 Rim and 2014 King Fires.

Current status on the threat of wildfire—

While recent studies indicate that California spotted owls continue to occupy sites that experience low-moderate severity and mixed-severity wildfire, the threshold of the proportion of high-severity fire that owls can tolerate within their territory is unknown. No information exists on long-term survival, reproduction, and fitness of owls within burned territories. Further, no information is available to assess owl foraging behavior and habitat use patterns at territories that experience 50 to 100 percent high-severity fire. There is no information available to evaluate how landscape-scale population density is affected by large fires. These information gaps are important given increases in the amounts and patch sizes of large-scale, stand-replacing fires in the Sierra Nevada (Miller et al. 2009, 2012; chapter 5).

California spotted owls may exhibit both short- and long-term responses to fire. Owls may persist over the short term even when habitat quality is reduced because of site fidelity. No information is available about short- versus long-term occupancy dynamics and demographic relationships to fire and habitat quality. While recent research suggests owls persist in territories after low-moderate and some mixed-severity fire, current and projected future increases in the amount and patch sizes of high-severity fire is an increasing threat to owl viability.

Integration of Forest Management and Wildfire

A key recommendation from CASPO was the need to develop, test, and monitor forest management strategies that reduce fuels accumulation and increase stand and landscape-scale heterogeneity to provide habitat for California spotted owls (McKelvey and Weatherspoon 1992). Limited progress has been made toward evaluating these activities of forest management (see Stephens et al. 2014, Tempel et al. 2014 for examples). Simulation studies have suggested that fuels reduction and forest restoration treatments may be compatible with reducing fire risk and providing owl habitat (Ager et al. 2012, Gaines et al. 2010, Lee and Irwin 2005, Roloff et al. 2012). However, no empirical studies have been conducted to test and validate modelling predictions. Recent work by Tempel et al. (2015) suggests that fuels treatments may provide long-term benefits to California spotted owls if sites experience fire under extreme conditions, but in the absence of fire, fuels treatments can have long-term negative effects on owls. Recent increasing trends in high-severity fire amounts and patch sizes (Miller 2009, Miller and Stafford 2012) coupled with projected future increases in high-severity fire under future climate scenarios (Liu et al. 2013, Westerling et al. 2006) emphasize the risk posed by high-severity fire to owl viability. Comprehensive, spatially explicit population models are not available to estimate how many owls and in what distributional pattern are needed to provide a high probability of sustaining a viable population and how owl population size and territory quality are predicted to change under alternative fuels reduction and forest restoration scenarios. Of particular note, large trees are well-documented to be key habitat elements for owl nesting and roosting; however, large trees are declining across the Sierra Nevada, driven by multiple factors acting separately or synergistically including logging, hazard tree removal, drought, insect mortality, fire suppression (increased stress owing to competition with other trees), wildfire, and climate change (Dolanc et al. 2014, Knapp et al. 2013, Lutz et al. 2009). The fundamental need to develop and test integrated strategies to reduce fire risk, restore forests, and provide habitat for a viable owl population identified by CASPO remains unresolved.

Areas of Concern: Gaps in the Distribution of California Spotted Owls in the Sierra Nevada

Beck and Gould (1992) reported that there appeared to be no gaps in the distribution of owls in the Sierra Nevada. However, they identified eight land areas of concern (AOCs) within the Sierra Nevada where potential gaps in the distribution could develop because of the following conditions: (1) naturally fragmented distribution of habitat and owls, (2) populations become isolated, (3) habitat becomes highly fragmented, and (4) areas where crude density of owls becomes low (table 7-2, fig. 7-10). No research is available to assess change in owl numbers or distribution across each of the AOCs. However, AOCs 2 (Northern Plumas County) and 4 (Northern Eldorado County) could be assessed for the long-term demographic monitoring study areas on the Lassen and Eldorado National Forests where owl populations have been declining (Conner et al. 2013, Tempel and Gutierrez 2013, Tempel et al. 2014) (chapter 4). Extensive forest management treatments have been implemented within AOCs 1 (Lassen County) and 3 (Northeastern Tahoe National Forest), while AOCs 5 (Northwestern Stanislaus National Forest) and 8 (Northeastern Kern County) have experienced extensive wildfire from 1990 through 2013. AOC 7 (Northwestern Sierra National Forest) also has experienced lower levels of disturbance (app. 7-1).

Table 7-2—Descriptions and reasons for areas of concern identified in the assessment of the California spotted owl report

Area number	Name	Reason for concern
1	Lassen County (FS, NPS, IP)	Habitat in this area is discontinuous, naturally fragmented, and poor in quality owing to drier conditions and lava-based soils.
2	Northern Plumas County (FS, IP, pvt.)	A gap in known distribution, mainly on private lands, extends east-west in a band almost fully across the width of the owl’s range.
3	Northeastern Tahoe NF (FS, IP, pvt.)	An area of checkerboard lands; much dominated by granite outcrops and red fir forests; both features guarantee low owl densities.
4	Northern Eldorado NF (FS, IP, pvt.)	Checkerboarded lands and large, private inholdings; owl densities unknown on some private lands and very low on others.
5	Northwestern Stanislaus NF (FS, IP, pvt.)	Has large private inholdings; owl densities unknown on most private lands.
6	Southern Stanislaus NF (FS)	Burned in recent years; the little remaining habitat is highly fragmented.
7	Northwestern Sierra NF (FS)	Habitat naturally fragmented, owing partly to low elevations and dry conditions; fragmentation accentuated by logging.
8	Northeastern Kern County (FS)	Only small, semi-isolated groups of owls in the few areas at elevations where habitat persists at the south end of the Sierra Nevada.

Ownership codes: FS = USDA Forest Service; NF = national forest, NPS = National Park Service; IP = industrial private lands; pvt. = multiple, small, private ownerships.

Source: Verner et al. 1992; fig. 14, p. 47 and discussion p. 45.

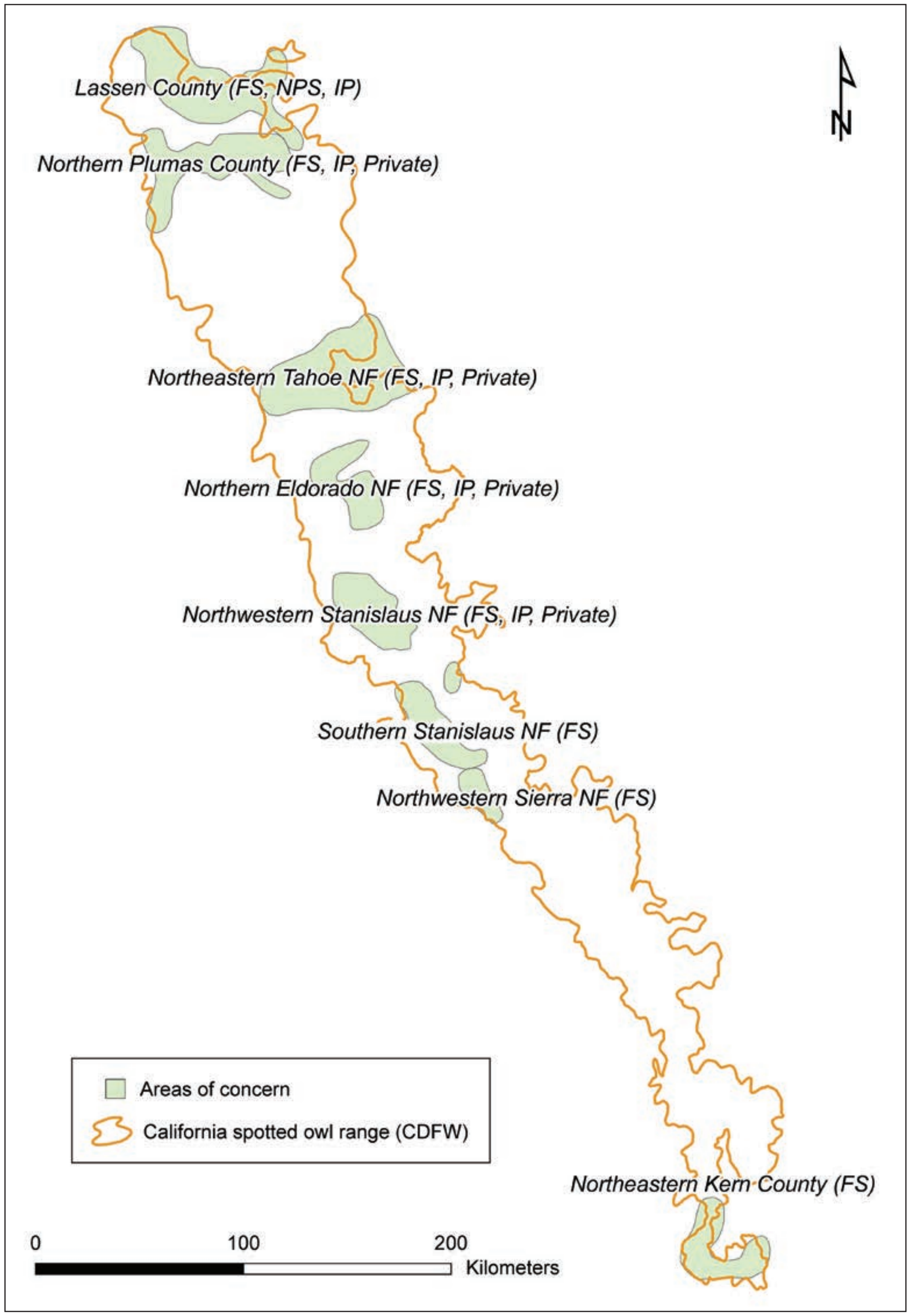

Figure 7-10—Areas of concern identified in the California spotted owl assessment area (CASPO) report (1992) where land ownership, topographic features, habitat fragmentation or amounts that may lead to future gaps in the distribution of California spotted owl populations or habitat in the Sierra Nevada. FS = Forest Service, NPS = National Park Service, IP = private industrial lands, CDFW = California Department of Fish and Wildlife.

Available evidence indicates that the threat of gaps in distribution has likely increased since CASPO. Documented owl population declines in AOCs 2 and 4, along with uncertainty about the status of owls within AOCs 1, 3, 5, and 8 where extensive forest management treatments have occurred, contribute to the increased threat. Development of gaps in owl distribution in the Sierra Nevada could have negative demographic effects because dispersal among geographic areas likely would be reduced. Spotted owls in the Sierra Nevada have low genetic diversity (chapter 4), and future fragmentation and isolation of owl populations within the Sierra could lead to further reductions in genetic diversity.

Human Development

McKelvey and Weatherspoon (1992) identified human population growth as a threat to owls and their habitat within the low to mid elevations of the Sierra Nevada. No information is available to evaluate effects of human population and residential development growth on owls and their habitat. Low- and mid-elevation zones of the west slope of the Sierra Nevada continue to experience growing human populations, expansion of communities, and increased dispersed, low-density housing (FRAP 2010). These human-induced changes result in habitat loss, habitat degradation, disturbance, and increased fuels treatments and forest thinning in wildland-urban-interface (WUI) zones to protect communities. About 50 percent of known owl sites occur within WUIs. Despite extensive forest management conducted within WUIs, no monitoring studies have been conducted to evaluate effects. These sites provide an opportunity to examine, retrospectively, the effects of fuels treatments and forest thinning on owls and their habitat.

Evaluation of Emerging Threats

Barred Owls

Barred owl range expansion has posed a significant threat to the viability of the northern spotted owl (Gutiérrez et al. 2007, Weins et al. 2014). Along with past and current habitat management, barred owls are considered a primary threat to northern spotted owl persistence (USFWS 2011). Barred owls have invaded western North America over the past century (Livezey 2009). Barred owls were first documented in British Columbia in 1943, and have dispersed southward through Washington, Oregon, and California (USFWS 2011). They are now sympatric across the entire range of the northern spotted owl (Gutiérrez et al. 2007). Barred owls are currently expanding their range into the Sierra Nevada and are an increasing threat to California spotted owls (Dark et al. 1998, Keane 2014).

Ecology and interactions with spotted owls—
Gutiérrez et al. (2007) predicted that two similar-sized, congeneric owls in newly established areas of sympatry would likely compete and that stable coexistence was unlikely. Recent work indicates this is occurring through competition for food and habitat as well as interference competition with barred owls being the dominant species (Dugger et al. 2011; Wiens et al. 2014; Yackulic et al. 2012, 2014). For example, northern spotted owl detection rates and site occupancy probabilities are lower in the presence of barred owls (Bailey et al. 2009; Crozier et al. 2006; Dugger et al. 2011; Kroll et al. 2010; Olson et al. 2005; Yackulic et al. 2012, 2014), with increased extinction probabilities and decreased colonization probabilities when barred owls are present (Dugger et al. 2011, Olson et al. 2005, Yackulic et al. 2014).

Dugger et al. (2011) reported that site occupancy dynamics of northern spotted owls were correlated through an additive interaction of habitat and barred owls. Extinction probabilities increased as the amount of old-forest habitat decreased around core areas, and these probabilities increased by a factor of two to three times when barred owls were detected. Colonization probabilities ranged from 0.33 to 0.73 and decreased with increasing fragmentation of older forest around core areas, and were much lower (0.03 to 0.20) when barred owls were detected. Occupancy probabilities increased when the proportion of old forest increased, and decreased with increasing fragmentation, and occupancy probabilities decreased dramatically when barred owls were present regardless of habitat condition (Dugger et al. 2011). Dugger et al. (2011) also noted that barred owls were increasing on their study area and had not reached an equilibrium population size and that the relationship between habitat and barred owls may change as barred owls continue to increase.

Yackulic et al. (2012) modeled hypothesized relationships between barred owls on spotted owls. Theoretically, these relationships were influenced by local and regional population sizes of each species that affects the numbers of recruits available for colonization (Yackulic et al. 2012), and dynamic patterns of competition that shift over time in response to the populations sizes of both species and amounts of important habitat types (Yackulic et al. 2014). Yackulic et al. (2012) also predicted that both the regional occupancy status of barred owls (i.e., regional population size available to produce recruits) and habitat were important factors affecting barred owl site occupancy dynamics. In contrast to previous speculation that habitat constraints would limit expansion of barred owls, Yackulic et al. (2012) concluded that habitat segregation would not likely limit either habitat use by barred owls or its numerical increase.

Yackulic et al. (2014) extended their previous work by examining the joint occupancy dynamics of barred and spotted owls over a 22-year period, as well as how intraspecific and interspecific occupancy dynamics were related to local competition, habitat, and local and regional population sizes. Dynamic changes in the availability of recruits to colonize sites for each species and their overlap in preferred habitat appeared to be key factors in determining the role of competition. Yackulic et al. (2014) found that including competition between the two species at the site scale resulted in increased extinction probabilities for spotted owls and reduced equilibrium occupancies, or population sizes, but was unlikely to lead to full competitive exclusion under the hypothesized scenarios they examined.

Competition between barred and spotted owls is likely because of broad overlap in their habitat use and diets (Hamer et al. 2001, 2007; Wiens et al. 2014) as well as the aggressive behavior of barred owls. Both species show similar preference for old-forest habitat with large trees and high canopy closures (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014), but barred owls use a broader suite of vegetation types (Hamer et al. 2007, Wiens et al. 2014). Spotted owls tend to use areas with steeper slopes relative to barred owls (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014). Using radio-marked birds, Wiens et al. (2014) estimated that mean overlap in proportional use of habitat types was 81 percent (range = 30 to 99 percent) and that both species used old-conifer forest (>120 years old) in greater proportion to its availability. In addition, both species used riparian-hardwood types along streams for foraging. Spotted owls concentrated foraging and roosting in forest patches with large trees (>19 in [>50 cm] d.b.h.) on steep slopes in ravines, whereas barred owls showed strongest associations with patches of large hardwood and conifer trees on relatively flatter slopes.

Wiens et al. (2014) further investigated spatial patterns of resource use between barred and spotted owls and found that home ranges overlapped between adjacent home ranges but that there was minimal overlap of core-use areas, suggesting that interference competition has resulted in interspecific territoriality. Spotted owl home ranges increased in size as the probability of barred owl presence increased, suggesting that spotted owls expanded their home ranges presumably to avoid barred owls. Further, relative probability of habitat use by spotted owls declined as a function of increased proximity to barred owl core areas. Wiens et al (2014) concluded that the patterns of spatial segregation and habitat use of these sympatric owls provided strong evidence of interference competition. Aggressive interactions between barred owls and spotted owls provided further support for interference competition and indicated that barred owls are the behaviorally dominant species (Van Lanen et al. 2011)

There is significant diet overlap between species, yet barred owls prey on more species (Hamer et al. 2001, Livezey and Bednarz 2007, Wiens et al. 2014). Both species prey primarily on small mammals, including flying squirrels, tree voles, woodrats, pocket gophers, mice, and lagomorphs, but barred owls also prey on a wider variety of terrestrial and aquatic prey, and diurnally active prey such as tree squirrels, birds, and reptiles (Hamer et al. 2001, Wiens et al. 2014). Diet overlap also appears to vary regionally and seasonally possibly because of spatial and temporal variation in prey availability and abundance (Graham 2012, Hamer et al. 2001, Wiens et al. 2014). Wiens et al. (2014) concluded that similarity in habitat use patterns and dietary overlap provided evidence for exploitative competition between the species, and that the magnitude of this competition may vary over space and time in response to variation in prey availability.

Barred owl home ranges are two to four times smaller than those of sympatric spotted owls (Hamer et al. 2007, Singleton et al. 2010, Wiens et al. 2014). Differences in home range sizes are likely a function of differences in diet; presumably the broader diet allows barred owls to meet their energetic demands with less foraging area. Thus, barred owls have the potential to reach population densities two to four times greater than spotted owls. Wiens et al. (2014) provided the first evidence of demographic performance of the species. Over the course of their study, barred owls had higher survival estimates than spotted owls (0.92 vs. 0.81), and barred owl pairs produced an average of 4.4 times more young than spotted owl pairs over the 3-year study period. Spotted owl pairs nesting within 0.9 mi (1.5 km) of a nest used by barred owls failed to successfully produce, and the number of young produced increased linearly with increasing distance from a barred owl core area (Wiens et al. 2014).

Barred owl removal experiments—

Barred owl removal experiments have been started to test the effects of barred owls on northern spotted owls and to assess whether removal may be a feasible management strategy (Diller 2013; Diller et al. 2012; USFWS 2008, 2011). Preliminary results suggested that barred owl presence causes declines in spotted owl occupancy and reductions in spotted owl calling behavior (Crozier et al. 2006, Diller et al. 2012). Diller et al. (2012) removed barred owls from nine historical northern spotted owl sites located on private timberland in northern California. All sites were reoccupied by spotted owls within 1 year. One site was occupied by a female not detected for 7 years, while overall, four sites were occupied by the original resident spotted owls and five sites were occupied by new, unknown spotted owls. Barred owls again displaced spotted owls at three sites in 1 to 4 years after initial removal. Diller et al. (2012) hypothesized that preliminary results suggested that barred owl removal may have broader positive neighborhood effects on spotted owls by increasing density of owls, which serves as a cue to settlement by dispersing owls (see Seamans and Gutierrez 2006).

Barred owl status and distribution within the range of the California spotted owl—
Through 2013, 51 barred and 27 "sparred" (hybrids between the two species) owls, and 1 unknown (fig. 7-11) (Keane, unpublished data) have been detected in the Sierra Nevada. None have been found in either southern or central coastal California. All sightings are incidental because no formal surveys for barred owls have been conducted.

The first record of barred owl detected in the Sierra Nevada was in Lassen County in 1989 (Keane, unpublished data). Only four owls (three barred owls, one sparred owl) were found between 1989 and 2001 and were limited to Sierra, Plumas, and Lassen Counties in the northern Sierra Nevada and southern Cascade Range (Dark et al. 1998, Keane unpublished data). There was an extensive survey effort by the USFS to inventory spotted owls from 1987 through 1992, which established a baseline for barred owls. Detections of barred and sparred owl increased between 2002 and 2013, largely because of increased spotted owl survey effort on spotted owl demographic study areas in the northern Sierra and southern Cascade Range. The first detections in the central and southern Sierra Nevada were in 2004 (Seamans et al. 2004, Steger et al. 2006). Six barred owls were detected in the southern Sierra Nevada during 2011–2012. 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 National Forest demography study area in 2013. This is the pattern observed in the range of the northern spotted owl—a slow increase followed by a rapid one.

The invasion of the barred owl into the Sierra Nevada poses a significant threat to California spotted owls. Based on the limited observations discussed above, it is possible that they will ultimately colonize the entire Sierra Nevada. Without control efforts, barred owls can potentially become a primary threat to the California spotted owl in the Sierra Nevada.

Climate Change

Climate change is projected to have significant effects on Sierra Nevada forests (GEOS Institute 2013[3] Lenihan et al. 2008; chapter 5). Long-term climate change may have both direct and indirect effects on the owl. Increases in temperature and

[3] **GEOS Institute. 2013.** Future climate, wildfire, hydrology, and vegetation projections for the Sierra Nevada, California: a climate change synthesis in support of the vulnerability assessment/adaptation strategy process. Unpublished report. On file with: Geos Institute 84 Fourth Street, Ashland, OR 97520.

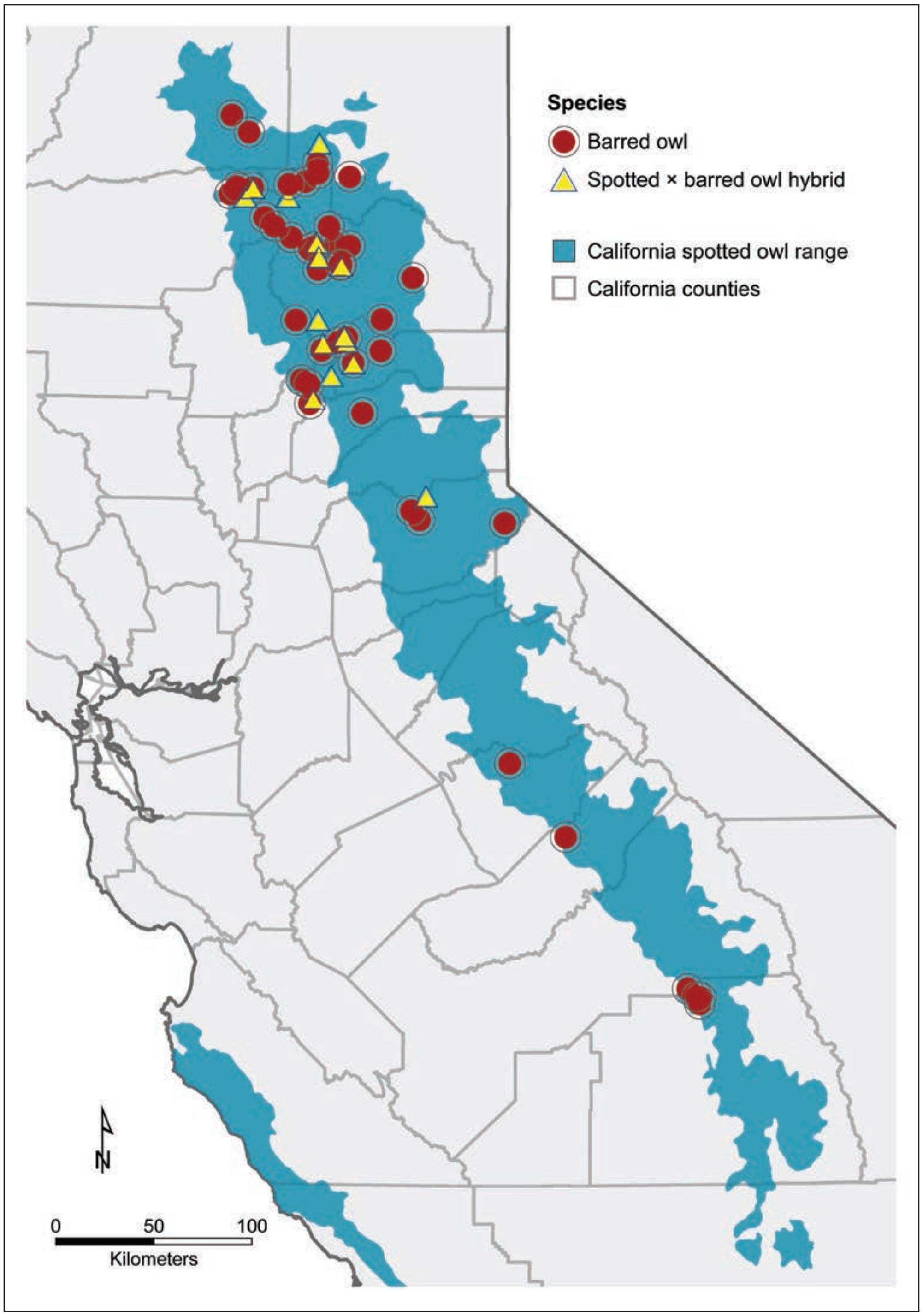

Figure 7-11—Barred owl and sparred owl records within the range of the California spotted owl in the Sierra Nevada, 1989–2013.

changes in precipitation patterns may have direct effects on spotted owl physiology, survival, reproduction, recruitment, and population growth. Climate change may also precipitate indirect effects such as (1) geographical shifts in habitat distribution, abundance, and quality; (2) increase of high-severity wildfire; (3) increase in mature/large tree mortality caused by insects and disease; (4) changes in prey distribution, abundance, and population dynamics; (5) changes in interspecific interactions with competitors and predators; and (6) changes in disease dynamics associated with changing temperature and precipitation patterns.

Weathers et al. (2001) determined the thermal profile, upper and lower critical temperatures, and basal and field metabolic rates of California spotted owls. The thermal neutral zone ranged from 18.2 to 35.2 °C. Above the upper critical temperature, owls experienced heat stress at rates greater than predicted for birds of similar size. Many studies have documented the negative effects of wet, cold weather during the winter and early-breeding season on spotted owl reproduction (Dugger et al. 2005, Franklin et al. 2000, Olson et al. 2004), survival (Franklin et al. 2000, Glenn et al. 2011, Olson et al. 2004), recruitment (Franklin et al. 2000), and population growth (Glenn et al. 2010). Wet, cold winter weather may increase energetic demands on owls by raising thermoregulation energy costs or reducing availability of prey and hunting success during inclement weather, which may negatively affect survival and reproduction. Wet, cold weather during the early breeding season may affect spotted owls by reducing egg viability owing to chilling, cause direct mortality of nestlings, or lower prey abundance or availability (Rockweit et al. 2012). Inclement winter weather may also affect recruitment through overwinter mortality of dispersing juvenile spotted owls (Franklin et al. 2000; Glenn et al. 2010, 2011).

Increases in late summer precipitation have been linked to increased survival, recruitment, and reproduction (Glenn et al. 2010, 2011; Olson et al. 2004; Seamans et al. 2002). Late-season precipitation may either reduce negative effects of summer drought, support greater plant production and primary productivity such as seeds and fungi that are important food for small mammal prey, or support increases in prey species abundance and availability. Drought and hot temperatures during the previous summer have been linked to lower survival and recruitment of spotted owls (Franklin et al. 2000, Glenn et al. 2011).

Across their range, spotted owls exhibit population-specific demographic responses to local weather and regional climates (Franklin et al. 2000; Glenn et al. 2010, 2011; Peery et al. 2012). These results indicate that population-specific variation may lead to population-specific responses to future climate scenarios, which may range from neutral to significantly negative effects and increased vulnerability (Glenn 2011, Glenn et al. 2010, Peery et al. 2012).

Glenn et al. (2010, 2011) investigated relationships among survival, recruitment, and population growth rate of six northern spotted owl populations in Oregon and Washington relative to local weather and regional climate. Local weather and regional climate variables explained 3 to 85 percent of the annual variation in growth rate in these populations, with the relative importance of weather and climate factors varying among the six populations. Peery et al. (2012) similarly found evidence for population-specific and regional variation in the relationship between spotted owl survival and reproduction with climate and projected response to future climate scenarios. Mexican spotted owl populations in New Mexico and Arizona were negatively associated with hot, dry conditions, and populations were projected to decline rapidly under future climate scenarios. In contrast, a population of California spotted owls in the mountains of southern California was negatively associated with cold, wet springs, with the population projected to exhibit low response to projected future climate conditions. In general, projected population growth rates were more affected by changes in temperature than precipitation, and by stronger climate effects on reproduction than survival (Peery et al. 2012).

Seamans and Gutiérrez (2007b) reported that temperature and precipitation during incubation most affected reproductive output, and conditions in winter associated with the Southern Oscillation Index (SOI) most affected adult survival on the Eldorado National Forest. Weather variables explained a greater proportion of the variation in reproductive output than they did survival. Further, these two weather variables were also included in the best models predicting annual population growth rate (Seamans and Gutiérrez 2007b). Subsequently, MacKenzie et al. (2012) found that SOI or other weather variables explained little variation in annual reproduction for this same population of owls over a longer time series. Unlike results for California spotted owls in southern California reported in Peery et al. (2011), subsequent analyses testing for effects of weather variables on demographic parameters showed no clear temporal associations for owls on the Eldorado National Forest in the Sierra Nevada. Other than the assessment conducted for the population of California spotted owls in the mountains of southern California (Peery et al. 2012), no studies have conducted similar analyses relating spotted owl demographic parameters (survival, reproduction, recruitment, and population growth) to climate variables and subsequently projected population growth under future climate scenarios for any California spotted owl populations in the Sierra Nevada.

In addition to direct effects on spotted owl vital rates, climate-induced changes in temperature, precipitation, and water moisture may lead to shifts in the distribution of California spotted owls. Siegel et al. (2014) assessed the potential vulnerability of California spotted owls in the Sierra Nevada to future climate scenarios using

NatureServe's Climate Change Vulnerability Index (CCVI) and predicted California spotted owls to be presumed stable over the next 50 years under the climate scenarios they investigated. Carroll (2010) recommended that ecological niche models based on temperature and precipitation envelopes have value for projecting potential effects of climate change on spotted owl distribution, although these types of coarse models have limitations because they do not incorporate additional important factors. A more rigorous assessment of climate change on spotted owls requires development of dynamic models that relate owl vital rates or occupancy to vegetation dynamics and effects of competitor and key prey species, in addition to climate variables.

Responses of California spotted owls to climate change are likely to be governed by complex interactions of factors that directly affect owls and their habitat, as well as indirect factors that can affect habitat (e.g., insect pests, disease, increased fire risk, vegetation type conversions, and distributional shifts) and ecological relationships (e.g., disease, competitors, predators, prey). While ecological niche models suggest that projected changes in temperature and precipitation may have minimal effects on California spotted owl distribution in the Sierra Nevada, results from demographic assessments and projections suggest that future climate change may have population-specific effects that likely will vary over geographical, elevational, and ecological gradients. Further, climate change projections of future vegetation distribution in the Sierra Nevada suggest that much of the low- and mid-elevation forests that currently comprise owl habitat are vulnerable to conversion of forests to woodlands, shrublands, and grasslands, especially with increased fire probabilities (chapter 5).

Climate change has emerged as a threat to California spotted owls in the Sierra Nevada given uncertainty regarding direct and indirect effects on owls and the potential for significant effects on the distribution and amounts of owl habitat. This threat may be partially mitigated over ecological time scales if mixed-conifer forests advance upslope, thereby providing habitat for owls where none now exists (e.g., Peery et al. 2012). However, it should be recognized that individual plant species exhibit species-specific responses to changes in temperature and precipitation, with vegetation communities reorganizing as a result of individual species responses (Briles et al. 2011; Davis 1981, 1986). Climate change may result in novel future vegetation communities that differ in species composition and richness relative to contemporary communities. Further, large trees that function as nest trees for owls and help moderate within-stand temperatures require many decades to centuries to attain large diameters and complex structures. Thus, it may require long time periods to develop the large tree vertical structure used by owls in areas where such structure does not now exist.

Disease, Parasites, and Contaminants

Little information exists on disease prevalence in spotted owl populations, and no information exists about the effects of disease on individual fitness or population viability. West Nile virus (WNV), a primarily mosquito-borne flavivirus that was first detected in eastern North America in 1999 and then throughout California by 2004, has been a concern (Reisen et al. 2004). West Nile virus has been demonstrated to be highly lethal to owls (Gancz et al. 2004, Marra et al. 2004). The primary route of infection is through the bite of an infected mosquito, with secondary routes of infection possible through consumption of infected prey and possibly feces (Kipp et al. 2006, Komar et al. 2003).

There has been no evidence to indicate that WNV has affected California spotted owl populations. Hull et al. (2010) screened samples for WNV antibodies from 209 California spotted owls collected from the southern (Sierra National Forest, Sequoia and Kings Canyon National Parks) or northern (Plumas and Lassen National Forests) Sierra Nevada during 2004–2008. Positive test results for antibodies would indicate exposure and survival (Hull et al. 2010). Results were negative for all 209 California spotted owls. Hull et al. (2010) hypothesized that populations either may have had little to no exposure to WNV, or infected birds had high mortality and were not available to be sampled, or no birds attained detectable immune response by antibody titers. However, because spotted owls have high annual survival rates, it is possible that WNV has not yet made a large impact on these birds (Blakesley et al. 2010, Conner et al. 2013). Because there is no general surveillance program through the Sierra Nevada, it has been unclear if owls have been locally affected by WNV or if climate change will change the disease dynamics.

Several species of ectoparasites (Hunter et al. 1994, Young et al. 1993), endoparasites (Gutiérrez 1989; Hoberg et al. 1989, 1993), and blood parasites (Gutiérrez 1989, Ishak et al. 2008) have been identified in spotted owls. Gutiérrez (1989) reported 100 percent blood parasite infection rates across all three spotted owl subspecies, suggesting long-term adaptation to high parasitism rates. Ishak et al. (2008) reported a prevalence of 79 percent for blood parasites of California spotted owls in the northern Sierra Nevada, with 79 percent of individuals positive for at least one infection, while 44 percent of individuals tested positive for multiple infections (Ishak et al. 2008). Ishak et al. (2008) reported that infection rates were higher in California spotted owls (79 percent) than in northern spotted owls (52 percent) and west coast barred owls (15 percent). Ishak et al. (2008) documented the first case of a *Plasmodium* sp. infection in a northern spotted owl and noted that barred owls may pose the risk of introducing novel infections into spotted owl populations. High rates of infection in California spotted owls compared to barred owls may position them at a competitive disadvantage compared to barred owls (Ishak et al. 2008), or the opposite could be true. The potential effects of parasites on spotted owl behavior, survival, or reproductive success has not been studied. However, disease and parasites can interact with other stressors to affect the condition of individuals, resulting in lower survival or other impacts.

Environmental contaminants have not been identified as potential ecological stressors on California spotted owls. However, recent reports of high exposure rates of fisher (*Pekania pennanti*) to rodenticides, likely associated with illegal marijuana cultivation, across the southern Sierra Nevada (Gabriel et al. 2012) may have implications for spotted owls and other forest carnivores, as they feed extensively on rodents. Ongoing research has reported 62 percent exposure of barred owls (44/71 owls) to rodenticides on the Hupa Reservation in northern California.[4]

Available evidence suggests that disease and parasites do not pose a significant threat at the current time, although WNV remains a possible future threat. Rodenticides pose a significant emerging threat to California spotted owls, though no information is available at the time to evaluate the magnitude and demographic consequences of this threat. High exposure rates recently recorded in barred owls in an area where they are sympatric with spotted owls indicates that spotted owls likely have experienced high exposure rates given broad dietary overlap between the species.

Human Recreation and Disturbance

Disturbance resulting from human recreation and management activities can potentially affect California spotted owls. Impacts from recreation can range from the presence of hikers near owl nests and roosts to loud noises made by chainsaws or motorized vehicles. Additionally, disturbances can be acute (short term) or chronic (long term) depending on the type of impact. Measures of behavioral response or fecal corticosterone hormone levels (hormones that reflect stress) have been used to assess spotted owl response to disturbance.

Mexican spotted owls exhibited low behavioral responses of any type to hikers who were ≥55 m (≥180 ft) distance, and juveniles and adults were unlikely to flush from hikers at distances >12 or >24 m (>39 or 78 ft), respectively (Swarthout and Steidl 2001). Additionally, owls did not change their behavior when hikers were near nests, although cumulative effects of high levels of recreational hiking near

[4] **Higley, M. 2016.** Personal communication. Wildlife biologist, Hoopa Valley Tribal Forestry, 40 Orchard St., Hoopa, CA 95546.

nests may be detrimental (Swarthout and Steidl 2003). No differences in reproductive success were observed between Mexican spotted owl nests exposed to helicopter and chainsaw noise; however, owls exhibited behavioral responses to both stimuli but with greater behavioral response to chainsaw noise than helicopter noise (Delaney et al. 1999). Results from this study supported management guidelines of a 400-m (0.25-mi) disturbance buffer around active Mexican spotted owl nests. Wasser et al. (1997) reported higher corticosterone levels in male northern spotted owls within 0.41 km (0.25 mi) of roads in Washington, suggesting that higher stress levels were correlated with proximity to roads. In contrast, Tempel and Gutiérrez (2003, 2004) found little evidence for disturbance effects from chainsaws and roads, as measured by fecal corticosterone hormone levels for California spotted owls in the central Sierra Nevada. Recently, Hayward et al. (2011) reported a more complex association between road noise and northern spotted owl response on the Mendocino National Forest in California. They found no association between baseline hormone levels and distance to roads. Rather, owls had higher corticosterone levels when exposed to continuous traffic exposure, and they found that owl response may vary with age of owls and physiological body condition. Of note, they reported lower reproductive success for owls near roads with continuous loud noise versus owls near quiet roads.

The effect of disturbance will likely remain high across the Sierra Nevada, but probably localized in space and time. Current limited operating period (LOPs) management standards and guidelines used on national forest lands that limit noise within 400 m of nest/roost areas during the nesting period appear effective for mitigating acute, direct noise and activity disturbance on owls at the project level.

Genetics

Current information supports the subspecies classification of California spotted owls. Further, genetic differences between California spotted owl populations in the Sierra Nevada and southern California owls suggests that these populations could be considered as distinct management units. Within the Sierra Nevada, genetic variation is low, raising concern that adaptation to future environmental change may be constrained (chapter 4). Further reduction in genetic diversity of owls in the Sierra Nevada is likely to be an increasing threat if current population declines continue and gaps in owl distribution develop. However, the types of genetic assays completed so far are not reflective of adaptive genetic traits, so additional genetic work needs to be done.

Chapter Summary

California spotted owls are faced with significant threats. Overall, the population of this subspecies appears to be declining, although population trajectories differ between national forest and national park lands (see chapter 4). The CASPO identified timber harvest and even-aged forest management, fire suppression and increased wildfire, potential development of gaps in distribution, and human development as threats to these owls (Verner et al. 1992). These threats have remained or increased since publication of the CASPO report. Since CASPO, range expansion of barred owls, climate change, contaminants, and low genetic diversity have arisen as additional significant threats.

Forest management remains a primary factor for California spotted owl habitat and populations on national forest and private industrial forest lands. Timber harvest on national forest lands has declined over the past few decades and most timber volume taken from the Sierra Nevada is harvested from private land. McKelvey and Weatherspoon (1992) identified both even-aged forest management and fire suppression as threats to California spotted owls and their habitat. They recommended development and experimental evaluation of forest management strategies to reduce fuel accumulation and the presence of ladder fuels and their associated risk of high-severity fire; increase vegetation heterogeneity at stand and landscape scales; and produce habitat to maintain populations of California spotted owls. Little progress has been made toward testing the effects of forest management strategies and silvicultural prescriptions that reduce wildfire risk on California spotted owls and their habitat, even though many treatments have occurred since CASPO (but see Stephens et al. 2014 and Tempel et al. 2014 for exceptions). Forest management practices on both national forest and private lands have likely exacerbated the concerns expressed in CASPO (Seamans and Gutiérrez 2007a, Stephens et al. 2014, Tempel et al. 2014, Verner et al. 1992). Dominant management activities on national forests have been mechanical thinning and fire suppression, and there is growing recognition that standard prescriptions for thinning to reduce fuels promotes stand homogeneity, as does fire suppression. In addition, even-aged forest management on private lands has likely reduced the amount of older, large-diameter tree, closed-canopy forest habitat. Further, widespread declines in large trees, a key owl nesting and roosting habitat element, have been reported from across the Sierra Nevada. Emerging strategies that protect existing, and increase future recruitment of, large trees integrated with prescriptions that create tree clumps and canopy gaps hold promise for providing favorable habitat conditions for owls while reducing the risk of habitat loss to fire or climate change-driven drought and insect tree mortality.

Much has been learned about California spotted owl response to fire, although significant scientific uncertainty and concern remains regarding effects of large-scale, stand-replacing fire effects on owls and their habitat. Recent increases in the amounts and patch sizes of high-severity fire, such as observed on the 2013 Rim and 2014 King Fires, along with projected future increases in fire activity associated with climate change, indicate the increased risk associated with high-severity fire.

Declining owl populations, uncertainty about effects of Forest Service and private land forest management, and increasing risk of high-severity fire contribute to increased risk of gaps developing within the distribution of the owl in the Sierra Nevada. Owl populations are documented to have declined in two areas of concern identified in CASPO. Continued loss and degradation of habitat because of residential development on private lands, primarily at low and mid elevations, is an increasing threat given continuing human population growth across the west slope of the Sierra Nevada.

Range expansion of the barred owl into the Sierra Nevada poses a significant new threat to California spotted owls. Unlike the situation with northern spotted owls, it is unlikely to have contributed to documented declines of California spotted owls because their density is low and they are largely restricted to the northern Sierra Nevada. However, recent increases in their number and dispersal into the central and southern Sierra Nevada portend an expansion throughout the Sierra Nevada. If such an expansion follows the pattern within the northern spotted owl range, California spotted owls will likely face extirpation. Research has shown that barred owl removal is technically and economically feasible (Diller 2013).

Direct effects of climate change on California spotted owls are difficult to project and may differ along elevational and latitudinal gradients across the Sierra Nevada. Of particular concern are related impacts of climate change such as drought and its indirect impacts on owl habitat characteristics and important habitat elements such as large trees, as well as the potential for vegetation type conversions from conifer forest types to hardwood, shrub, and grass vegetation types within the low- and mid-elevation zones of the Sierra Nevada. Recent reports of wildlife contamination from rodenticides associated with illegal marijuana cultivation in the Sierra Nevada poses an increasing threat to California spotted owls and their prey. To date, no available evidence has demonstrated negative effects of West Nile virus on California owls, though this remains a potential threat given high mortality from this disease that has been observed in many captive owl species. Disturbance from human management and recreational activities does not appear to be a significant threat to California spotted owls as existing standards and guidelines (e.g., LOPs) appear to be sufficient for mitigating direct, short-duration effects of forest management activities (e.g., timber harvest, prescribed fire, etc.), while recreational effects appear to be localized with potential impacts to a few owl sites.

Evaluating the current status of threats to California spotted owls is hampered by lack of reliable information on the current status, and recent trends, of California spotted owl habitat across the Sierra Nevada. Given the preeminent importance of understanding the current status and past trends in owl populations and habitat, lack of such habitat information could be considered a threat to successful owl management and conservation, as well as for comprehensive forest management for wildlife. Further detailed discussion of owl habitat mapping issues is presented in chapter 6.

Based on the best scientific information available, there are significant threats to California spotted owls that have either increased in magnitude or arisen since CASPO (Verner et al. 1992). The most significant primary threats are (1) continued effects of forest management on both public and private land; (2) increasing trends in large-scale, stand-replacing fire; (3) invasion of barred owls; (4) potential climate change direct effects on owl populations or climate-driven vegetation type conversions and increased fire activity; and (5) increasing human population growth and development. Two additional issues that can potentially become significant threats are (1) illegal rodenticide use and (2) West Nile virus. These threats can potentially, functioning singly or in concert, contribute to development of gaps in the distribution of owls, which can have negative demographic consequences for owls. For example, climate change, fire, and forest management activities may interact to limit the amounts and distribution of habitat available to owls, which can be further affected by increases in the barred owl population. This overall threat assessment coupled with documented ongoing declines in owl populations clearly indicates the need for careful management, monitoring, and research to address key uncertainties for these threats.

Significant challenges exist for addressing the multiple threats to owls and for developing forest management strategies that integrate owl conservation needs within the broader context of forest ecosystem management and restoration in the face of increasing fire risk and climate change. Over 20 years have passed and only limited progress has been made toward resolving the questions, threats, and challenges posed in the CASPO report. Progress will involve development and testing forest management strategies, with success predicated upon increased organizational capacity and effective collaboration between management and research.

Literature Cited

Ager, A.A.; Vaillant, N.M.; Finney, M.A.; Preisler, H.K. 2012. Analyzing wildfire exposure and source-sink relationships on a fire prone forest landscape. Forest Ecology and Management. 267: 271–283.

Bailey, L.L.; Reid, J.A.; Forsman, E.D.; Nichols, J.D. 2009. Modeling co-occurence of northern spotted owls and barred owls: accounting for detection probability differences. Biological Conservation. 142: 2983–2989.

Beck, T.W.; Gould, G.I., Jr. 1992. Background and the current management situation for the California spotted owl. In: Verner, J.; McKelvey, J.K.; Noon, B.R.; Gutiérrez, R.J.; Gould, G.I., Jr.; Beck, T.W., tech. coords. The California spotted owl: a technical assessment of its current status. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 37–53.

Berigan, W.J.; Gutiérrez, R.J.; Tempel, D.J. 2012. Evaluating the efficacy of protected habitat areas for the California spotted owl using long-term monitoring data. Journal of Forestry. 110(6): 299–303.

Blakesley, J.A.; Seamans, M.E.; Conner, M.M.; Franklin, A.B.; White, G.C.; Gutiérrez, R.J.; Hines, J.E.; Nichols, J.D.; Shaw, D.W.H.; Munton, T.E.; Keane, J.J.; Steger, G.N.; Noon, B.R.; McDonald, T.L.; Britting, S. 2010. Population dynamics of spotted owls in the Sierra Nevada, California. Wildlife Monographs. 174.

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

Bond, M.L.; Lee, D.E.; Siegel, R.B.; Ward, J.P.J. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management. 73(7): 1116–1124.

Briles, C.E.; Whitlock, C.; Skinner, C.N.; Mohr, J. 2011. Holocene forest development and maintenance on different substrates in the Klamath Mountains, northern California, USA. Ecology. 92(3): 590–601.

Carroll, C. 2010. Role of climatic niche models in focal-species-based conservation planning: assessing potential effects of climate change on northern spotted owl in the Pacific Northwest, USA. Biological Conservation. 143(6): 1432–1437.

Clark, D.A.; Anthony, R.G.; Andrews, L.S. 2013. Relationship between wildfire, salvage logging, and occupancy of nesting territories by northern spotted owls. Journal of Wildlife Management. 77(4): 672–688.

Conner, M.M.; Keane, J.J.; Gallagher, C.V.; Jehle, G.; Munton, T.E.; Shaklee, P.A.; Gerrard, R.A. 2013. Overall realized population change for long-term monitoring: California spotted owl case study. Journal of Wildlife Management. 77(7): 1449–1458.

Crozier, M.L.; Seamans, M.E.; Gutiérrez, R.J.; Loschl, P.J.; Horn, R.B.; Sovern, S.G.; Forsman, E.D. 2006. Does the presence of barred owls suppress the calling behavior of spotted owls? The Condor. 108(4): 760–769.

Dark, S.J.; Gutiérrez, R.J.; Gould, G.I., Jr. 1998. The barred owl (*Strix varia*) invasion in California. The Auk. 115(1): 50–56.

Davis, M.B. 1981. Quaternary history and the stability of forest communities: forest succession. New York: Springer: 132–153.

Davis, M.B. 1986. Climatic instability, time lags, and community disequilibrium. In: Diamond, J.M.; Case, T.J., eds. Community ecology. New York: Harper & Row: 269–284.

Delaney, D.K.; Grubb, T.G.; Beier, P.; Pater, L.L.; Reiser, M.H. 1999. Effects of helicopter noise on Mexican spotted owls. Journal of Wildlife Management. 63(1): 60–75.

Diller, L.; Hamm, K.; Lamphear, D.; McDonald, T. 2012. Two decades of research and amonitoring of northern spotted owls on private timberlands in the redwood region: what do we know and what challenges remain? In: Standiford, R.B.; Weller, T.J.; Piirto, D.D.; Stuart, J.D., eds. Proceedings of coast redwood forests in a changing California: a symposium for scientists and managers. Gen. Tech. Rep. PSW-GTR-238. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 399–407.

Diller, L.V. 2013. To shoot or not to shoot: the ethical dilemma of killing one raptor to save another. The Wildlife Professional. Winter: 54–57.

Dolanc, C.R.; Safford, H.D.; Thorne, J.H.; Dobrowski, S.Z. 2014. Changing forest structure across the landscape of the Sierra Nevada, California, since the 1930s. Ecosphere. 5: 1–26.

Dugger, K.M.; Anthony, R.G.; Andrews, L.S. 2011. Transient dynamics of invasive competition: barred owls, spotted owls, habitat, and the demons of competition present. Ecological Applications. 21(7): 2459–2468.

Dugger, K.M.; Wagner, F.; Anthony, R.G.; Olson, G.S. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor. 107: 863–878.

Franklin, A.B.; Anderson, D.R.; Gutiérrez, R.J.; Burnham, K.P. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs. 70(4): 539–590.

Franklin, A.B.; Gutiérrez, R.J.; Nichols, J.D.; Seamans, M.E.; White, G.C.; Zimmerman, G.S.; Hines, J.E.; Munton, T.E.; LaHaye, W.S.; Blakesley, J.A.; Steger, G.N.; Noon, B.R.; Shaw, D.W.H.; Keane, J.J.; McDonald, T.L.; Britting, S. 2004. Population dynamics of the California spotted owl (*Strix occidentalis occidentalis*): a meta-analysis. Ornithological Monographs. 54: 56.

Fire and Resource Assessment Program [FRAP]. 2010. California forest and rangelands assessment. California Department of Forestry and Fire Protection. http://frap.cdf.ca.gov/assessment/2010/assessment2010.php. (January 2015).

Gabriel, M.W.; Woods, L.W.; Poppenga, R.; Sweitzer, R.A.; Thompson, C.; Matthews, S.M.; Higley, J.M.; Keller, S.M.; Purcell, K.; Barrett, R.H.; Wengert, G.M.; Sacks, B.N.; Clifford, D.L. 2012. Anticoagulant rodenticides on our public and community lands: spatial distribution of exposure and poisoning of a rare forest carnivore. PLoS ONE. 7(7): e40163.

Gaines, W.L.; Harrod, R.J.; Dickinson, J.; Lyons, A.L.; Halupka, K. 2010. Integration of northern spotted owl habitat and fuels treatments in the eastern Cascades, Washington. Forest Ecology and Management. 260: 2045–2052.

Gancz, A.Y.; Barker, I.K.; Lindsay, R.; Dibernardo, A.; McKeever, K.; Hunter, B. 2004. West Nile virus outbreak in north American owls, Ontario, 2002. Emerging Infectious Diseases. 10(12): 2135–2142.

Ganey, J.L.; Ward, J.P., Jr.; Jenness, J.S.; Block, W.M.; Hedwall, S.; Jonnes, R.S.; Apprill, D.L.; Rawlinson, T.A.; Kyle, S.C.; Spangle, S.L. 2014. Use of protected activity centers by Mexican spotted owls in the Scaramento Mountains, New Mexico. Journal of Raptor Research. 48(3): 201–218.

Glenn, E.M.; Anthony, R.G.; Forsman, E.D. 2010. Population trends in northern spotted owls: associations with climate in the Pacific Northwest. Biological Conservation. 143(11): 2543–2552.

Glenn, E.M.; Anthony, R.G.; Forsman, E.D.; Olson, G.S. 2011. Local weather, regional climate, and annual survival of the northern spotted owl. Condor. 113(1): 159–176.

Graham, S.A. 2012. Diet compostition, niche and geographic characteristics, and prey size preference of barred owls (*Strix varia*) in the Pacific Northwest. Boise, ID: Boise State University. 169 p.

Gutiérrez, R.J. 1985. Information and research needs for spotted owl management. In: Gutiérrez, R.J.; Carey, A.B., tech. eds. Ecology and management of the spotted owl in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-185. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 115–118.

Gutiérrez, R.J. 1989. Hematozoa from the spotted owl. Journal of Wildlife Diseases. 25(4): 614–618.

Gutiérrez, R.J.; Cheng, A.S.; Becker, D.R.; Cashen, S.; Ganz, D.; Gunn, J.; Liquori, M.; Merrill, A.; Saah, D.S.; Price, W. 2015. Legislated collaboration in a conservation conflict: a case study of the Quincy Library Group, California. In: Redpath, S.; Gutiérrez, R.J.; Wood, K.; Young, J.C., eds. Conflicts in conservation: navigating towards solutions. Cambridge, United Kingdom: Cambridge Unversity Press: 271–283.

Gutiérrez, R.J.; Cody, M.; Courtney, S.; Franklin, A.B. 2007. The invasion of barred owls and its potential effect on the spotted owl: a conservation conundrum. Biological Invasions. 9: 181–196.

Hamer, T.E.; Forsman, E.D.; Glenn, E.M. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. Condor. 109(4): 750–768.

Hamer, T.E.; Hays, D.L.; Senger, C.M.; Forsman, E.D. 2001. Diets of northern barred owls and northern spotted owls in an area of sympatry. Journal of Raptor Research. 35(3): 221–227.

Hayward, L.S.; Bowles, A.E.; Ha, J.C.; Wasser, S.K. 2011. Impacts of acute and long-term vehicle exposure on physiology and reproductive success of the northern spotted owl. Ecosphere. 2(6): art65.

Hoberg, E.; Cawthorn, R.J.; Hedstrom, O. 1993. Enteric coccidia (*Apicomplexa*) in the small intestine of the northern spotted owl (*Strix occidentalis caurina*). Journal of Wildlife Diseases. 29(3): 495–497.

Hoberg, E.; Miller, G.S.; Wallner-Pendleton, E.; Hedstrom, O. 1989. Helminth parasites of northern spotted owls (*Strix occidentalis caurina*) from Oregon. Journal of Wildlife Diseases. 25(2): 246–251.

Hull, J.M.; Keane, J.J.; Tell, L.; Ernest, H.B. 2010. West Nile Virus antibody surveillance in three Sierra Nevada raptors of conservation concern. Condor. 112(1): 168–172.

Hunter, J.E.; Gutiérrez, R.; Franklin, A.B.; Olson, D. 1994. Ectoparasites of the spotted owl. Journal of Raptor Research. 28(4): 232–235.

Irwin, L.L.; Clark, L.A.; Rock, D.C.; Rock, S.L. 2007. Modeling foraging habitat of California spotted owls. Journal of Wildlife Management. 71(4): 1183–1191.

Irwin, L.L.; Rock, D.F.; Rock, S.C. 2013. Do northern spotted owls use harvested areas? Forest Ecology and Management. 310(0): 1029–1035.

Ishak, H.D.; Dumbacher, J.P.; Anderson, N.L.; Keane, J.J.; Valkiūnas, G.; Haig, S.M.; Tell, L.A.; Sehgal, R.N.M. 2008. Blood parasites in owls with conservation implications for the spotted owl (*Strix occidentalis*). PLoS ONE. 3(5): e2304.

Keane, J.J. 2014. California spotted owl. In: Long, J.W.; Quinn-Davidson, L.; Skinner, C.N., eds. Science synthesis to promote resilience of social-ecological systems in the Sierra Nevada and southern Cascades. Gen. Tech. Rep. PSW-GTR-247. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 437–467.

Kipp, A.M.; Lehman, J.A.; Bowen, R.A.; Fox, P.E.; Stephens, M.R.; Klenk, K.; Komar, N.; Bunning, M.L. 2006. West Nile virus quantification in feces of experimentally infected American and fish crows. American Journal of Tropical Medicine and Hygiene. 75(4): 688–690.

Knapp, E.; North, M.; Benech, M.; Estes, B. 2012. The variable-density thinning study at Stanislaus-Tuolumne Experimental Forest. Managing Sierra Nevada Forests. Gen. Tech. Rep. PSW-GTR-237. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 127–140.

Knapp, E.; Skinner, C.K.; North, M.P.; Estes, B.L. 2013. Long-term overstory and understory change following logging and fire exclusion in a Sierra Nevada mixed-conifer forest. Forest Ecology and Management. 310: 903–914.

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

Kroll, A.J.; Fleming, T.L.; Irwin, L.L. 2010. Site occupancy dynamics of northern spotted owls in the eastern Cascades, Washington, USA. Journal of Wildlife Management. 74(6): 1264–1274.

Lee, D.C.; Irwin, L.L. 2005. Assessing risk to spotted owls from forest thinning in fire-adapted forests of the western United States. Forest Ecology and Management: 191–200.

Lee, D.E.; Bond, M.L. 2015. Occupancy of California spotted owl sites following a large fire in the Sierra Nevada, California. Condor. 117(2): 228–236.

Lee, D.E.; Bond, M.L.; Bochert, M.I.; Tanner, R. 2013. Influence of fire and salvage logging on site occupancy of spotted owls in the San Bernardino and San Jacinto mountains of southern California. Journal of Wildlife Management. 77: 1327–1341.

Lee, D.E.; Bond, M.L.; Siegel, R.B. 2012. Dynamics of breeding-season site occupancy of the California spotted owl in burned forests. Condor. 114(4): 792–802.

Lenihan, J.M.; Bachelet, D.; Neilson, R.P.; Drapek, R. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climatic Change. 87(1): 215–230.

Liu, Y.; Goodrick, S.L.; Stanturf, J.A. 2013. Future U.S. wildfire potential trends projected using a dynamically downscaled climate change scenario. Forest Ecology and Management. 294: 120–135.

Livezey, K.B.; Bednarz, J.C. 2007. Barred owl habitat and prey: a review and synthesis of the literature. Journal of Raptor Research. 41(3): 177–201.

Livezey, K.B. 2009. Range expansion of barred owls, part I: chronology and distribution. American Midland Naturalist. 161: 49–56.

Lutz, J.A.; van Wagtendonk, J.W.; Franklin, J.F. 2009. Twentieth-century decline of large-diameter trees in Yosemite National Park. Forest Ecology and Management. 257: 2296–2307.

MacKenzie, D.I.; Seamans, M.E.; Gutiérrez, R.J.; Nichols, J.D. 2012. Investigating the population dynamics of California spotted owls without marked individuals. Journal of Ornithology. 152(2): 597–604.

Marra, P.P.; Griffing, S.; Caffrey, C.; Kilpatrick, A.M.; McLean, R.; Brand, C.; Saito, E.; Dupuis, A.P.; Kramer, L.; Novak, R. 2004. West Nile Virus and wildlife. BioScience. 54(5): 393–402.

McKelvey, K.S.; Johnston, J.D. 1992. Historical perspectives on forests of the Sierra Nevada and the Transverse Ranges of Southern California: forest conditions at the turn of the century. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 225–246.

McKelvey, K.S.; Weatherspoon, C.P. 1992. Projected trends in owl habitat. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 261–273.

Miller, J.D.; Safford, H. 2012. Trends in wildfire severity: 1984 to 2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California, USA. Fire Ecology. 8(3): 41–57.

Miller, J.D.; Safford, H.D.; Crimmins, M.; Thode, A.E. 2009. Quantitative evidence for increasing fire severity in the Sierra Nevada and southern Cascade mountains, California and Nevada, USA. Ecosystems. 12: 16–32.

Noon, B.R.; Franklin, A.B. 2002. Scientific research and the spotted owl (*Strix occidentalis*): opportunities for major contributions to avian population ecology. The Auk. 119(2): 311–320.

Olson, G.S.; Anthony, R.G.; Forsman, E.D.; Ackers, S.H.; Loschl, P.J.; Reid, J.A.; Dugger, K.M.; Glenn, E.M. 2005. Modeling of site occupancy dynamics for nothern spotted owls with emphasis on the effects of barred owls. Journal of Wildlife Management. 69(3): 918–932.

Olson, G.S.; Glenn, E.M.; Anthony, R.G.; Forsman, E.D.; Reid, J.A.; Loschl, P.J.; Ripple, W.J.; Flaspohler 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management. 68(4): 1039–1053.

Peery, M.Z.; Gutiérrez, R.J.; Kirby, R.; LeDee, O.E.; LaHaye, W. 2012. Climate change and spotted owls: potentially contrasting responses in the Southwestern United States. Global Change Biology. 18(3): 865–880.

Reisen, W.; Lothrop, H.; Chiles, R.; Madon, M.; Cossen, C.; Woods, L.; Husted, S.; Kramer, V.; Edman, J. 2004. West Nile Virus in California. Emerging Infectious Diseases. 10: 1369–1378.

Roberts, S.L.; van Wagtendonk, J.W.; Miles, A.K.; Kelt, D.A. 2011. Effects of fire on spotted owl site occupancy in a late-succesional forest. Biological Conservation. 144: 610–619.

Rockweit, J.T.; Franklin, A.B.; Bakken, G.S.; Gutiérrez, R.J. 2012. Potential influences of climate and nest structure on spotted owl reproductive success: a biophysical approach. PLoS ONE 7(7): e41498.doi:1371/journal.pone.0041498.

Roloff, G.J.; Mealey, S.P.; Bailey, J.D. 2012. Comparative hazard assessment for protected species in a fire-prone landscape. Forest Ecology and Management. 277: 1–10.

Romesburg, H.C. 1981. Wildlife science: gaining reliable knowledge. Journal of Wildlife Management. 45: 293–313.

Schumaker, N.H.; Brookes, A.; Dunk, J.R.; Woodbridge, B.; Heinrichs, J.A.; Lawler, J.J.; Caroll, C.; LaPlante, D. 2014. Mapping sources, sinks, and connectivity using a simulation model of northern spotted owls. Landscape Ecology. 29: 579–592.

Seamans, M.E.; Corcoran, J.; Rex, A. 2004. Southernmost record of a spotted owl x barred owl hybrid in the Sierra Nevada. Western Birds. 35: 173–174.

Seamans, M.E.; Gutiérrez, R.J.; May, C.A. 2002. Mexican spotted owl population dynamics: influence of climatic variation on survival and reproduction. Auk. 119(2): 321–334.

Seamans, M.E.; Gutiérrez, R.J. 2006. Spatial dispersion of spotted owl sites and the role of conspecific attraction on settlement patterns. Ecology, Ethology, and Evolution. 18: 99–111.

Seamans, M.E.; Gutiérrez, R.J. 2007a. Habitat selection in a changing environment: the relationship between habitat alteration and spotted owl territory occupancy and breeding dispersal. Condor. 109: 566–576.

Seamans, M.E.; Gutiérrez, R.J. 2007b. Sources of variability in spotted owl population growth rate: testing predictions using long-term mark–recapture data. Oecologia. 152(1): 57–70.

Siegel, R.B.; Pyle, P.; Thorne, J.H.; Holguin, A.J.; Howell, C.A.; Stock, S.; Tingley, M. 2014. Vulnerability of birds to climate change in California's Sierra Nevada. Avian Conservation and Ecology. 9(1): 7 http://www.ace-eco.org/vol9/iss1/art7/. (January 2015).

Singleton, P.H.; Lehmkuhl, J.F.; Gaines, W.L.; Graham, S.A. 2010. Barred owl space use and habitat selection in the Eastern Cascades, Washington. Journal of Wildlife Management. 74(2): 285–294.

Stephens, S.L.; Bigelow, S.W.; Burnett, R.D.; Collins, B.M.; Gallagher, C.V.; Keane, J.; Kelt, D.A.; North, M.P.; Roberts, L.J.; Stine, P.A. 2014. California spotted owl, songbird, and small mammal responses to landscape fuel treatments. BioScience. doi: 10.1093/biosci/biu137.

Swarthout, E.C.; Steidl, R.J. 2001. Flush responses of Mexican spotted owls to recreationists. The Journal of Wildlife Management. 65(2): 312–317.

Swarthout, E.C.; Steidl, R.J. 2003. Experimental effects of hiking on breeding Mexican spotted owls. Conservation Biology. 17(1): 307–315.

Tempel, D.J.; Gutiérrez, R.J. 2003. Fecal corticosterone levels in California spotted owls exposed to low-intensity chainsaw sound. Wildlife Society Bulletin. 31(3): 698–702.

Tempel, D.J.; Gutiérrez, R.J. 2004. Factors related to fecal corticosterone levels in California spotted owls: implications for assessing chronic stress. Conservation Biology. 18(2): 538–547.

Tempel, D.J.; Gutiérrez, R.J. 2013. The relationship between occupancy and abundance for a territorial species, the California spotted owl. Conservation Biology. 27(5): 1087–1095.

Tempel, D.J.; Gutiérrez, R.J.; Battles, J.J.; Fry, D.L.; Su, Y.; Guo, Q.; Reetz, M.J.; Whitmore, S.A.; Jones, G.M.; Collins, B.M.; Stephens, S.L.; Kelly, M; Berigan, W.J.; Peery, M.Z. 2015. Evaluating short- and long-term impacts of fuels treatments and simulated wildfire on an old-forest species. Ecosphere. 6(12): Art 261.

Tempel, D.; Gutiérrez, R.J.; Whitmore, S.; Reetz, M.; Stoelting, R.; Berigan, W.; Seamans, M.E.; Peery, M.Z. 2014. Effects of forest management on California spotted owls: implications for reducing wildfire risk in fire-prone forests. Ecological Applications. 24(8): 2089–2106.

U.S. Department of the Interior, Fish and Wildlife Service [USFWS]. 2006. 50 CFR Part 17 Endangered and threatened wildlife and plants; 12-month finding for a petition to list the California spotted owl *(Strix occidentalis occidentalis)* as threatened or endangered. Federal Register. 71(100): 29886–29908.

U.S. Department of the Interior, Fish and Wildlife Service [USFWS]. 2008. Final recovery plan for the northern spotted owl (*Strix occidentalis caurina*). Portland, OR. 142 p. https://www.fws.gov/ecos/ajax/docs/recovery_plan/NSO_Final_Rec_Plan051408.pdf. (22 November 2016).

U.S. Department of the Interior, Fish and Wildlife Service [USFWS]. 2011. Revised recovery plan for the northern spotted owl (*Strix occidentalis caurina*). Portland, OR. 258 p.

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

Verner, J.; McKelvey, K.S.; Noon, B.R.; Gutiérrez, R.J.; Gould, G.I.; Beck, T.W. 1992. The California spotted owl: a technical assessment of its current status. Gen. Tech. Rep. PSW-GTR-133. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 285 p.

Wasser, S.K.; Bevis, K.; King, G.; Hanson, E. 1997. Noninvasive physiological measures of disturbance in the northern spotted owl. Conservation Biology. 11(4): 1019–1022.

Weathers, W.W.; Hodum, P.J.; Blakesley, J.A. 2001. Thermal ecology and ecological energetics of California spotted owls. Condor. 103: 678–690.

Weatherspoon, C.P.; Husari, S.J.; Van Wagtendonk, J. 1992. Fire and fuels management in relation to owl habitat in forests of the Sierra Nevada and southern California. Gen. Tech. Rep. PSW-GTR-133., Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 247–260.

Weatherspoon, C.P.; Skinner, C.N. 1996. Landscape-level strategies for forest fuel management. In: SNEP Science Team and Special Consultants, eds. Sierra Nevada ecossytem project: final report to Congress. Vol. II: assessments and scientific basis for management options. Report No. 37. Davis, CA: Centers for Water and Wildlands Resources, University of California–Davis: 1471–1492.

Westerling, A.L.; Hidalgo, H.G.; Cayan, D.R.; Swetnam, T.W. 2006. Warming and earlier spring increase western U.S. forest wildlfire activity. Science. 313: 940–943.

Wiens, J.D.; Anthony, R.G.; Forsman, E.D. 2014. Competitive interactions and resource partitioning between northern spotted owls and barred owls in western Oregon. Wildlife Monographs. 185(1): 1–50.

Williams, P.J.; Gutiérrez, R.J.; Whitmore, S. 2011. Home range and habitat selection of spotted owls in the central Sierra Nevada. Journal of Wildlife Management. 75(2): 333–343.

Yackulic, C.B.; Reid, J.; Davis, R.; Hines, J.E.; Nichols, J.D.; Forsman, E. 2012. Neighborhood and habitat effects on vital rates: expansion of the barred owl in the Oregon Coast Ranges. Ecology. 93(8): 1953–1966.

Yackulic, C.B.; Reid, J.; Nichols, J.D.; Hines, J.E.; Davis, R.; Forsman, E. 2014. The roles of competition and habitat in the dynamics of populations and species distributions. Ecology. 95(2): 265–279.

Young, K.E.; Franklin, A.B.; Ward, J.P. 1993. Infestation of northern spotted owls by hippoboscid (Diptera) flies in northwestern California. Journal of Wildlife Diseases. 29(2): 278–283.

Zabel, C.J.; Dunk, J.R.; Stauffer, H.B.; Roberts, L.M.; Mulder, B.S.; Wright, A. 2003. Northern spotted owl habitat models for research and management application in California, USA. Ecological Applications. 13(4): 1027–1040.

Zimmerman, G.S.; LaHaye, W.S.; Gutiérrez, R.J. 2003. Empirical support for a despotic distribution in a California spotted owl population. Behavioral Ecology. 14(3): 433–437.

Appendix 7-1—Distribution of Forest Management Treatments and Wildfire During 1990–2014 Within the Areas of Concern Identified in the 1992 CASPO Report

The following maps show the distribution of Forest Management Treatments and Wildfire During 1990–2014 Within the areas of concern Identified in the 1992 "The California Spotted Owl: A Technical Assessment of Its Current Status" CASPO report.

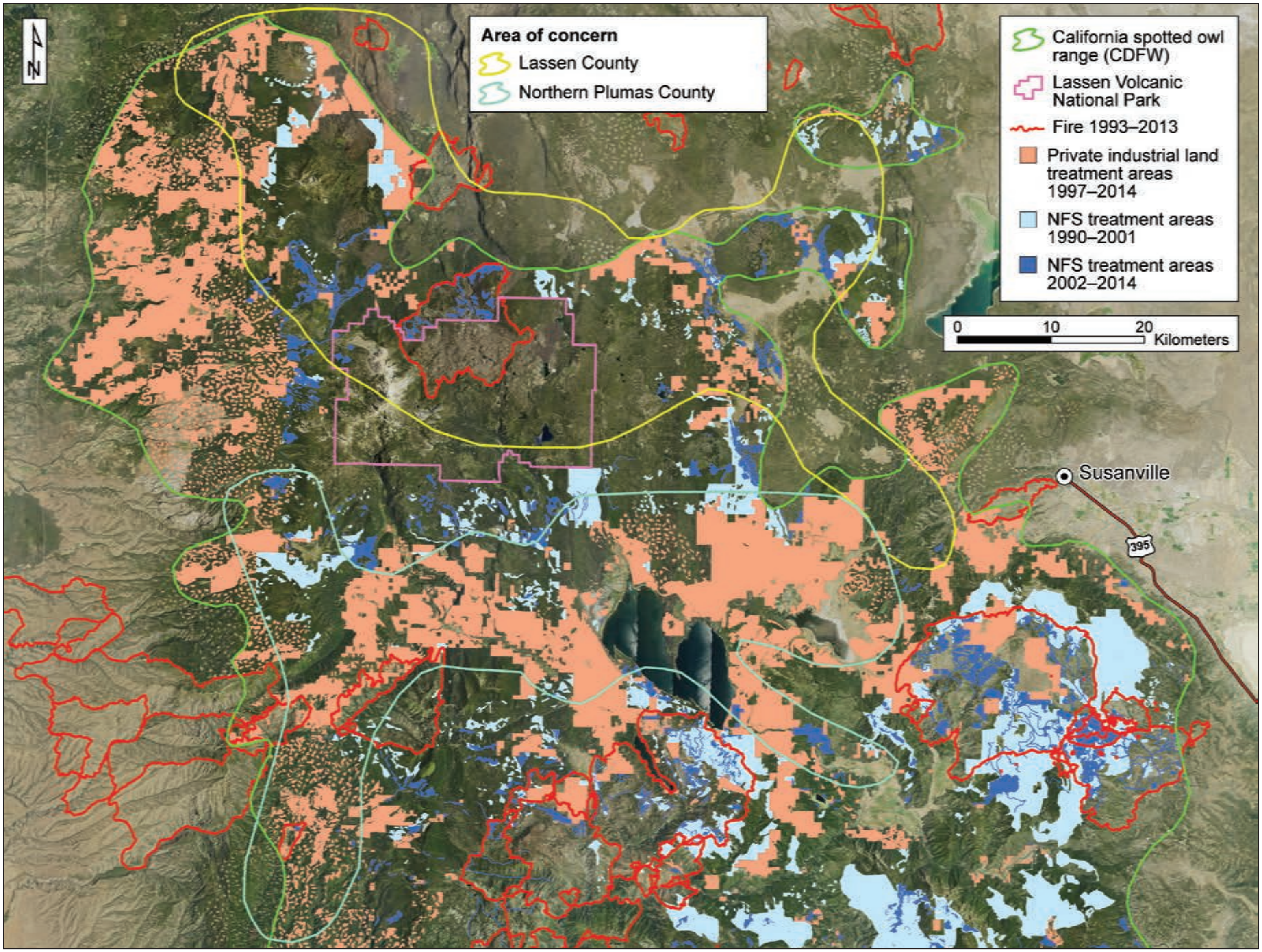

Figure A-1—Distribution of forest management treatments and wildfire on national forest and private industrial forest lands in the California spotted owl assessment (1992) areas of concern 1 (Lassen County) and 2 (Northern Plumas County) on the Plumas and Lassen National Forests, 1990–2014. Sources: National Forest System (NFS) treatments extracted from U.S. Forest Service (USFS) Forest Activities Tracking System courtesy of Joe Sherlock (Pacific Southwest Region [R5] silviculturist), private industrial treatments courtesy of California Department of Forestry Forest Practice Geographic Information System (Suzanne Lang), fire perimeters from USFS R5 vegetation burn severity data, National Agricultural Imagery Program photography from U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, owl range from California Department of Forestry, and Wildlife (CDFW), owl areas of concern from general technical report PSW-GTR-133 (1992).

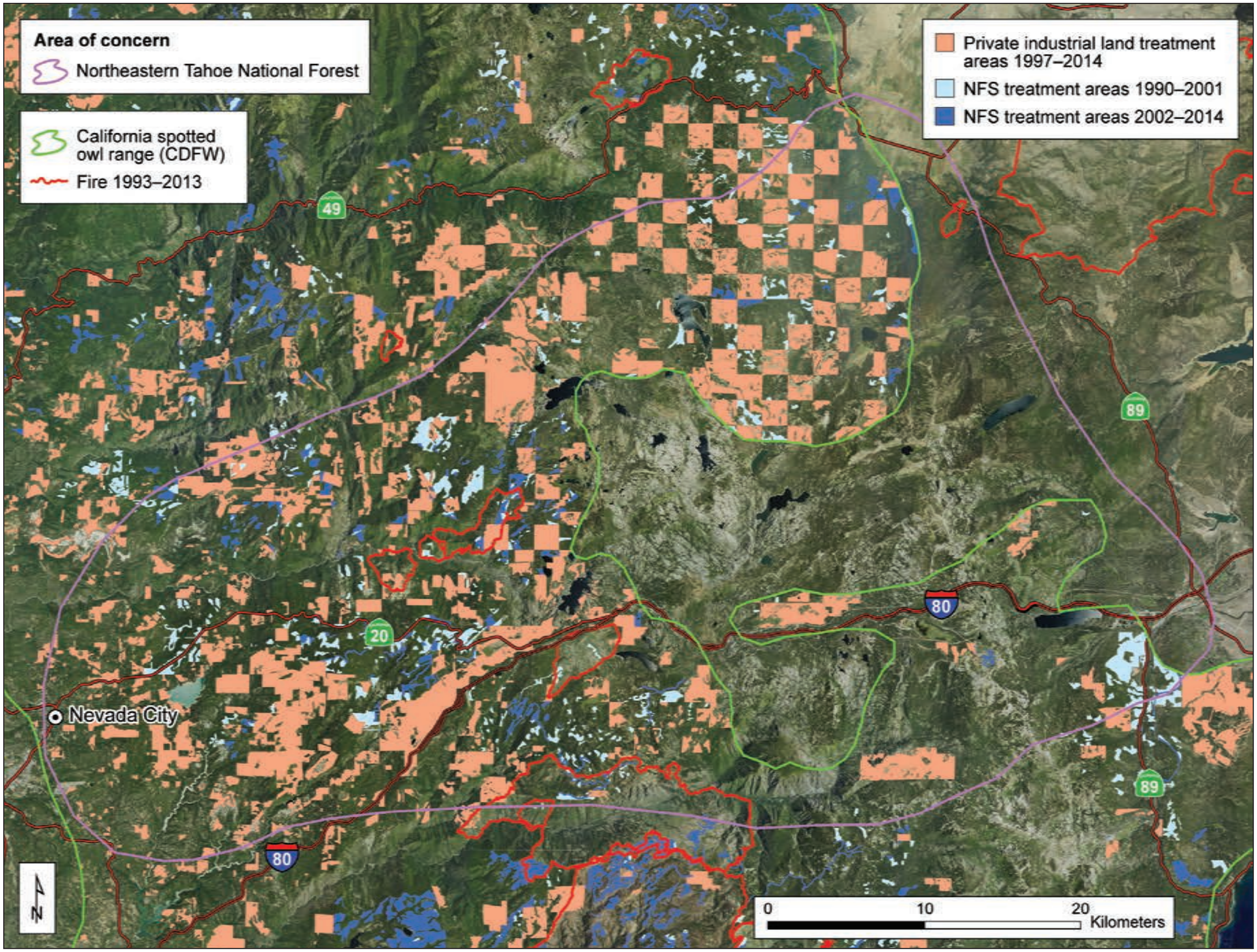

Figure A-2—Distribution of forest management treatments and wildfire on national forest and private industrial forest lands in the California spotted owl assessment (1992) area of concern 3 (Northeastern Tahoe National Forest) on the Tahoe National Forest, 1990–2014. Sources: National Forest System (NFS) treatments extracted from U.S. Forest Service (USFS) Forest Activities Tracking System courtesy of Joe Sherlock (Pacific Southwest Region [R5] silviculturist), private industrial treatments courtesy of California Department of Forestry Forest Practice Geographic Information System (Suzanne Lang), fire perimeters from USFS R5 vegetation burn severity data, National Agricultural Imagery Program photography from U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, owl range from California Department of Forestry and Wildlife (CDFW), owl areas of concern from general technical report PSW-GTR-133 (1992).

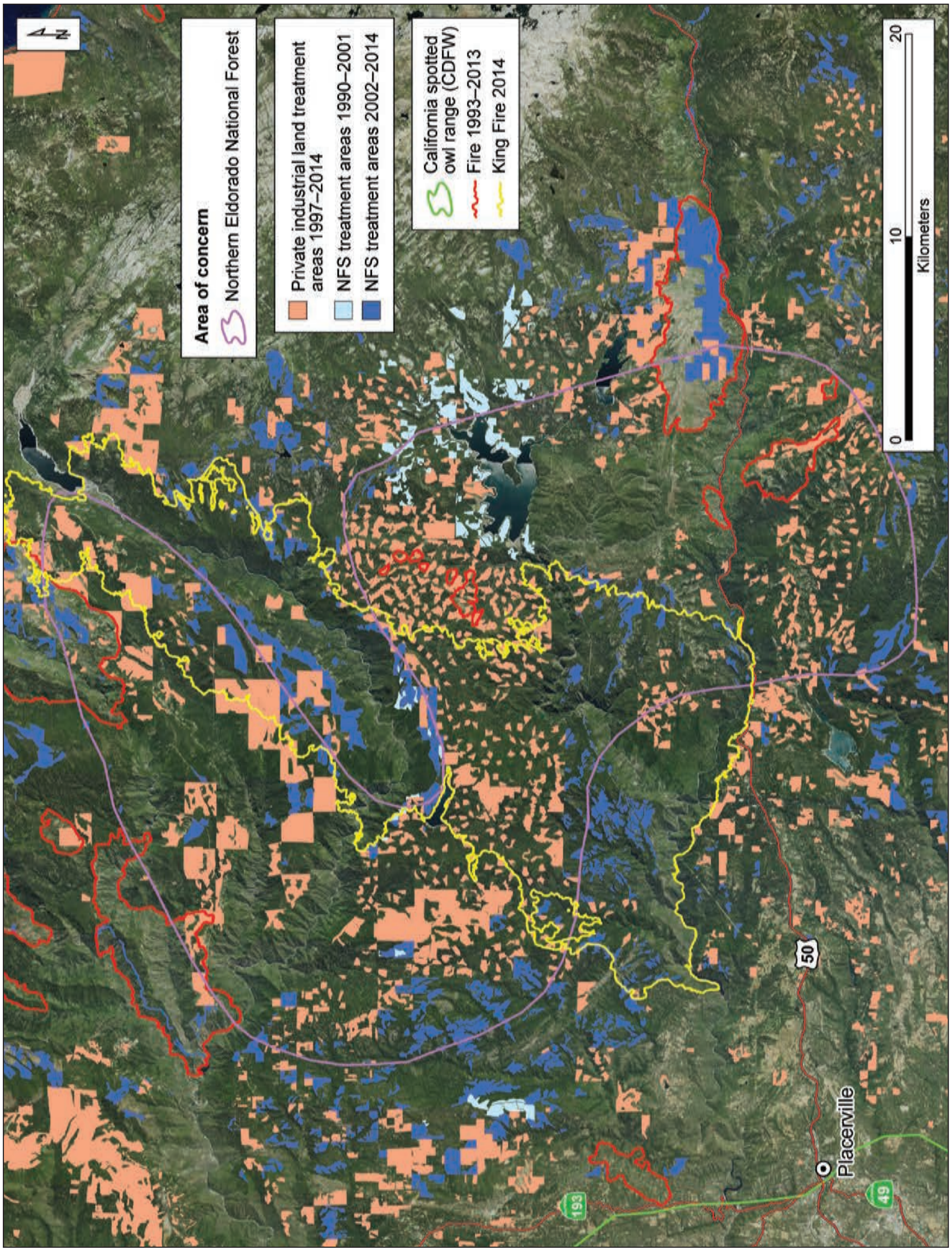

Figure A-3—Distribution of forest management treatments and wildfire on national forest and private industrial forest lands in the California spotted owl assessment (1992) area of concern 4 (Northern Eldorado National Forest) on the Eldorado National Forest, 1990–2014. Sources: National Forest System (NFS) treatments extracted from U.S. Forest Service (USFS) Forest Activities Tracking System courtesy of Joe Sherlock (Pacific Southwest Region [R5] silviculturist), private industrial treatments courtesy of California Department of Forestry Forest Practice Geographic Information System (Suzanne Lang), fire perimeters from USFS R5 vegetation burn severity data, National Agricultural Imagery Program photography from U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, owl range from California Department of Forestry and Wildlife (CDFW), owl areas of concern from general technical report PSW-GTR-133 (1992).

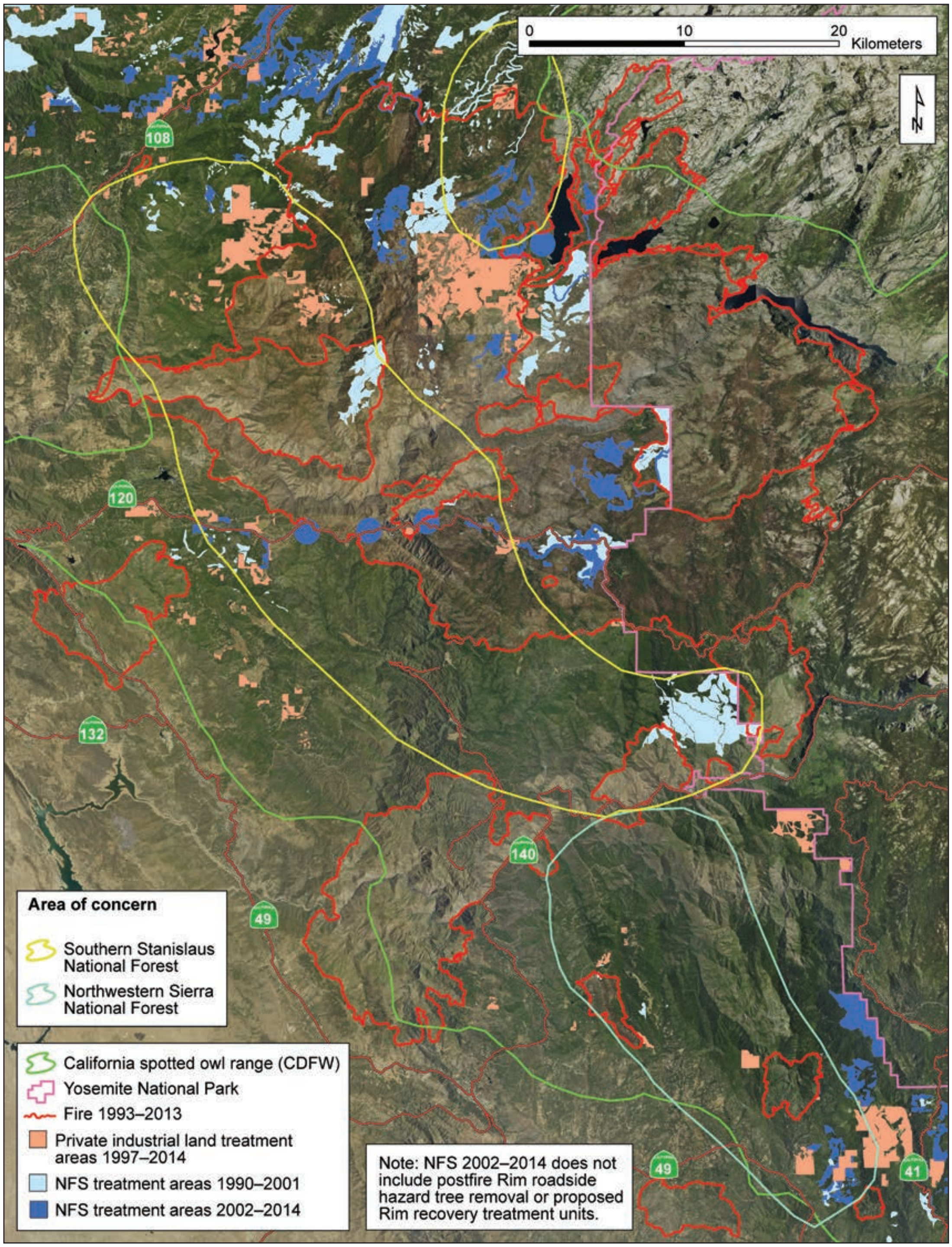

Figure A-4—Distribution of forest management treatments and wildfire on national forest and private industrial forest lands in the California spotted owl assessment (1992) areas of concern 6 (Southern Stanislaus National Forest) and 7 (Northwestern Sierra National Forest) on the Stanislaus and Sierra National Forests, 1990–2014. Sources: National Forest System (NFS) treatments extracted from U.S. Forest Service (USFS) Forest Activities Tracking System courtesy of Joe Sherlock (Pacific Southwest Region [R5] silviculturist), private industrial treatments courtesy of California Department of Forestry Forest Practice Geographic Information System (Suzanne Lang), fire perimeters from USFS R5 vegetation burn severity data, National Agricultural Imagery Program photography from U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, owl range from California Department of Forestry and Wildlife (CDFW), owl areas of concern from general technical report PSW-GTR-133 (1992).

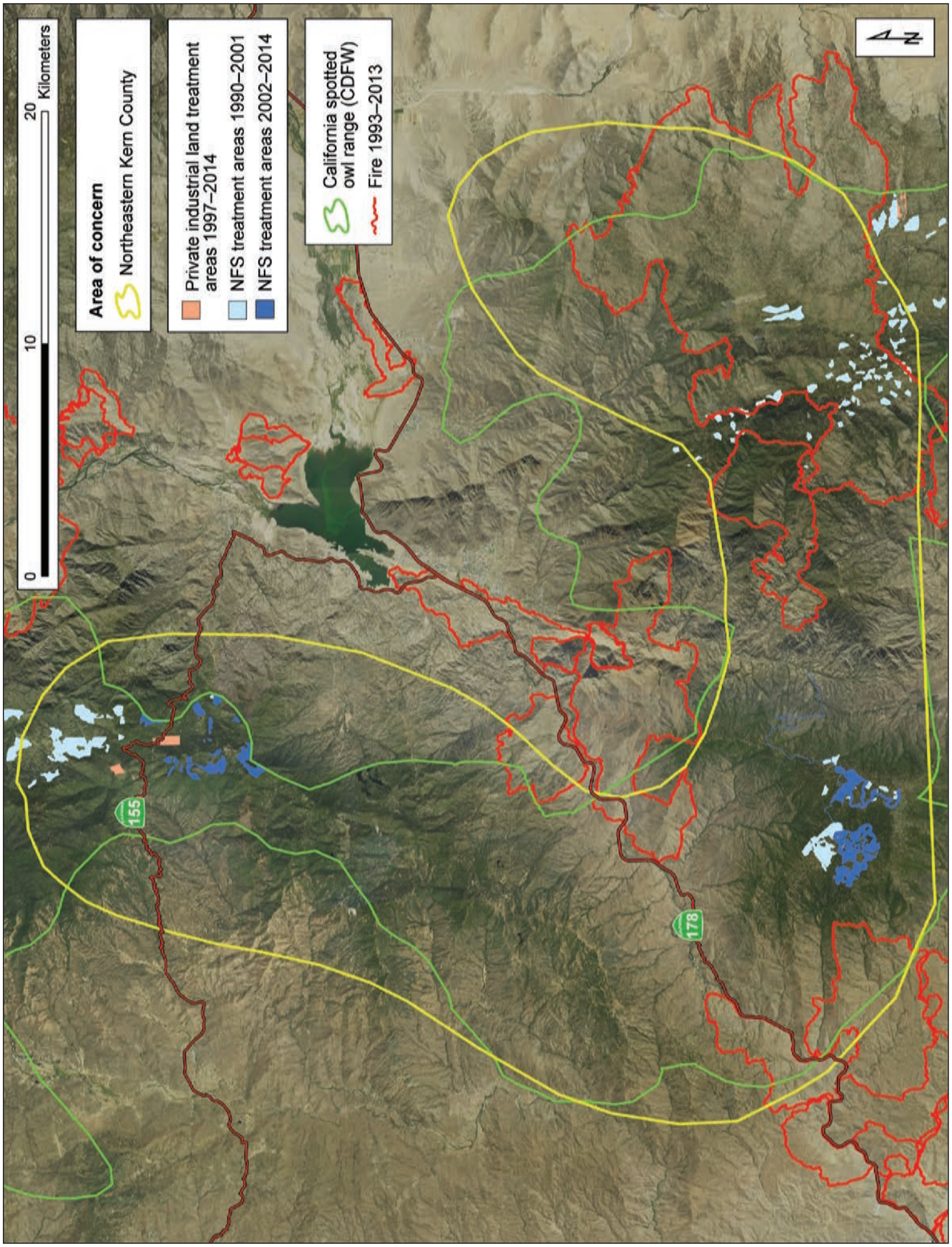

Figure A-5—Distribution of forest management treatments and wildfire on national forest and private industrial forest lands in the California Spotted Owl Assessment (1992) area of concern 8 (Northeastern Kern County) on the Sequoia National Forest, 1990–2014. Sources: National Forest System (NFS) treatments extracted from U.S. Forest Service (USFS) Forest Activities Tracking System courtesy of Joe Sherlock (Pacific Southwest Region [R5] silviculturist), private industrial treatments courtesy of California Department of Forestry Forest Practice Geographic Information System (Suzanne Lang), fire perimeters from USFS R5 vegetation burn severity data, National Agricultural Imagery Program photography from U.S. Department of Agriculture Farm Service Agency Aerial Photography Field Office, owl range from California Department of Forestry and Wildlife (CDFW), owl areas of concern from general technical report PSW-GTR-133 (1992).